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THESIS

**TECHNICAL MANAGEMENT OVERSIGHT
FRAMEWORK FOR INTERNATIONAL DEFENSE
ACQUISITION: PRESENTATION,
APPLICATION, AND ANALYSIS**

by

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ACQUISITION: PRESENTATION, APPLICATION, AND
ANALYSIS**

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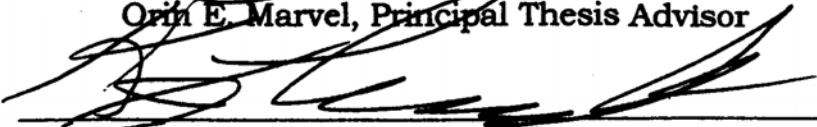

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ABSTRACT

This research paper proposes a framework for capturing and studying Technical Management Oversight (TMO) knowledge from past and ongoing international programs. Interviews were conducted with key program personnel from several programs to populate the framework with program data. Programs considered were HAWK, ROLAND, LANCE, MEADS, the International Space Station, and MLRS TGW. These programs had various degrees of international participation and various degrees of international coupling. Valuable insights were captured that can be applied to the structure and conduct of ongoing and future international programs. Among other conclusions, it is found that U.S. policy has not kept pace with international programs, the degree of international coupling within a program strongly affects management complexity and it is important to know the customers. Restrictions on technology transfer and release of information dramatically affect TMO. Cost share and work share issues strongly impact TMO, and patience and diplomacy are vital.

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I. INTRODUCTION

A. PURPOSE

This research paper advances understanding of technical management for complex, internationally acquired systems. A Technical Management Oversight (TMO) framework is used to present and analyze six significant international systems developed involving the United States Army and NASA.

B. BACKGROUND

The industrial revolution, fueled by commercial opportunity, spawned previously undreamed systems. These systems were made possible by application of the scientific method and the discovery of new materials and phenomenon. The discovery and investigation of electricity and the development of transistors, integrated circuits, computers and networks, continues to reshape our world.

New systems are being developed that are increasingly complex with competing requirements, containing multiple subsystems with millions of components, having computers with millions of lines of computer source code. The discipline of system engineering has emerged to address this complexity.

DoD engages in the development of complex systems. Many organizations are involved, playing different roles. Various approaches to contracting and distribution of development responsibility are used, involving varying degrees of contractor - contractor and Government - contractor teaming. The Program Management Office (PMO) is the DoD focus of control for execution of contracts, contractor oversight, and coordination with other government agencies. The prime contractor has the responsibility for fulfilling the contract. The Government program office must establish an appropriate technical management approach to satisfy regulatory and statutory requirements, to hold the contractor

accountable, and to overcome technical risk that cannot be directly addressed by the contractor. For international programs, due to security and technical transfer considerations, some TMO functions may be split between an International Program Office (IPO) and National Product Offices (NPOs) . This interface adds complexity and increases the importance of establishing “agreed to” TMO objectives.

C. RESEARCH QUESTIONS

1. PRIMARY RESEARCH QUESTION

- a. What is a candidate framework for understanding technical management oversight of international acquisition and how might that framework be applied to international Air and Missile Defense (AMD) programs?***

This question is answered by Chapter III, “Framework for Technical Management Oversight (TMO)” and Chapter IV, “TMO Framework Applied.” The write-ups in Chapter IV show the TMO framework to be an effective tool for documenting TMO for international programs.

2. SUBSIDIARY RESEARCH QUESTIONS

- a. What is the role and purpose of Technical Management Oversight for acquisition?***

The straightforward answer to this question can be found among the pages documenting interview results in chapter IV:

The role and purpose of TMO is to ensure the system being developed meets the User’s needs.

To be effective, TMO must (1) manage technical resources such as a Research Development and Engineering Center (RDEC) and technical support contractors; (2) manage technical requirements (3)

manage risk; (4) monitor contract performance; (5) coordinate User participation when necessary in the development process; and (6) define technical effort within contract statements of work.

b. What are the unique international TMO issues that must be jointly addressed by the participating U.S. National Program Office (NPO) and International Program Office (IPO) managers for an international system acquisition?

The answers to this question can be found among the pages documenting interview results in chapter IV. An international development program involving the U.S. may include one IPO and an NPO for each participating nation. The IPO will have primary responsibility for developing the system and managing a prime contractor, similar to a U.S. only program.

Security and control of U.S. technology information must be addressed. It is in the U.S. interest for the international program to be successful, but information that reveal vulnerabilities of other systems must be protected. The U.S. NPO will have responsibility to ensure proper authorizations are obtained before U.S. information is transferred to the IPO.

If a partial release of sensitive U.S. information is planned, then some technical support and separate development contracts managed by the NPO may be needed. Coordinating these separate but dependent development activities with the primary activity is critical.

The unique U.S. documentation to satisfy the U.S. acquisition process should be minimized.

Early involvement of the U.S. User requires careful coordination.

The NPO must help the U.S. User to understand whether or not U.S requirements are incorporated in the international program.

Where requirements shortfalls exist, the U.S. NPO must coordinate with the IPO and the other NPOs.

D. SCOPE AND LIMITATIONS

The scope of this thesis is limited to TMO for internationally acquired systems. Programs considered are tactical missile systems or missile defense systems managed from project offices located at Redstone Arsenal in Alabama. The International Space Station is also considered. For each program, the following are addressed:

- (1) Executive Control
- (2) National Interaction
- (3) TMO Funding
- (4) TMO Organizational Aspects
- (5) Research, Development and Engineering Center (RDEC)/Contractor Technical Support
- (6) Management of Technical Requirements
- (7) Management of Technical Risk
- (8) Technical Monitoring Capability
- (9) Direct Technical Contribution
- (10) Control of and Access to Technical Data
- (11) User Participation
- (12) Cost Share/Work Share Affecting TMO
- (13) Preparation of Contract Statements of Work
- (14) U.S. Acquisition Review Prior to Next Program Phase

The following are not addressed:

- (1) Preparation of the Operational Requirements Document (ORD)
- (2) Personnel Management Issues
- (3) Group Dynamics/Leadership

- (4) Operational Test Issues
- (5) Use of GOTS/COTS vs Developmental Items
- (6) Development Methodologies
- (7) Budget/Finance
- (8) Earned Value Monitoring
- (9) Contracts

E. RESEARCH METHODOLOGY

Research investigation included literature searches and detailed interviews with technically knowledgeable program leaders in past and ongoing international programs. The literature search included the following:

- (1) Regulatory requirements affecting TMO for U.S. Acquisitions,
- (2) International program considerations, and
- (3) System engineering principles and practices.

The interviews were guided by a common framework summarized in Figure 1 and detailed later. The interviews were open-ended technical discussions intended to identify issues associated with individual international programs and to identify common themes between the different programs considered.

F. ORGANIZATION OF THE STUDY

The thesis is organized into the following chapters:

Chapter I: Introduction -- Introduces the research topic, bounds the discussion and establishes the research methodology.

Chapter II: Literature Search – Summarizes pertinent information to establish a basis for discussion. Areas reviewed include the following:

A. Regulatory Requirements

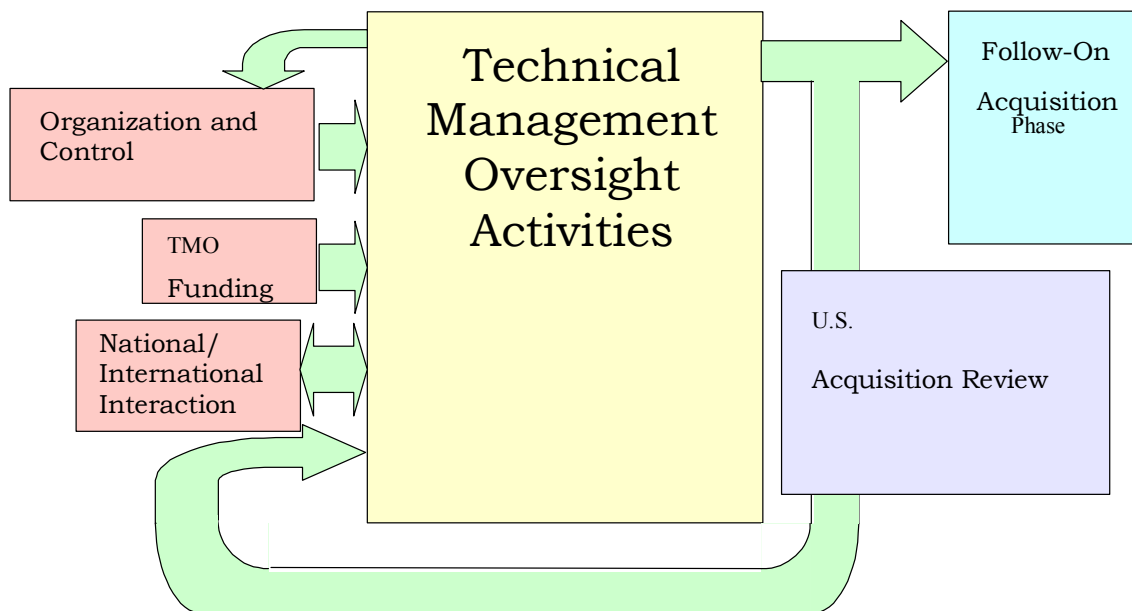


Figure 1: Technical Management Oversight Process

B. International Considerations

C. System Engineering Principles

Chapter III: TMO Framework -- Introduces a framework for describing TMO within an international program and describes how this framework will be applied to the programs considered in Chapter IV.

Chapter IV: Technical Management Oversight Framework Applied -- Describes technical management oversight for several past and present international programs using the framework described in chapter III as a guide. Systems selected for review are as follows:

A. HAWK

B. ROLAND

C. LANCE

D. Medium Extended Air Defense System (MEADS)

E. International Space Station (ISS)

F. Multiple Launch Rocket System (MLRS) Tactical Guided
Warhead (TGW)

Chapter V: Analysis, Conclusions and Recommendations –
Analyzes and Summarizes lessons learned from the interviews. For
common issues, recommendations are suggested.

G. RECOMMENDATION FOR FURTHER STUDY

- Investigate the international programs presented in this research paper from the perspective of the international partner.
- Optimize the framework presented here by eliminating redundant framework elements and apply this framework to Navy and Air Force programs.
- Take each element of the International TMO Framework and explore in a more in-depth fashion its application on a wide range of programs.

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II. LITERATURE SEARCH

A. STATUTORY AND REGULATORY ENVIRONMENT

1. Overview

The Executive Branch of Government and Congress establish the environment for military acquisition. Congress authorizes activities and provides funding while the President establishes his priorities, requests budgets from Congress and executes the acquisition process. The roles of Congress and the

The DoD acquisition system exists to secure and sustain the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. The Department's investment strategy must be postured to support not only today's force, but also the next force, and future forces beyond that. The primary objective of Defense acquisition is to acquire quality products that satisfy user needs with measurable improvements to mission accomplishment and operational support, in a timely manner, and at a fair and reasonable price.

(Introduction to Defense Acquisition Management).

President are established by the Constitution of the United States. Following budget approval, the Executive Branch Department of Defense (DOD) executes the defense acquisition process. Laws directly affect this process, and DOD 5000 Directives and Instructions provide a framework for acquisition. The Acquisition Executive (AE) from the Army, Navy, Air Force, or the Office of the Secretary of Defense (OSD) is responsible to establish the specific process to be followed by each acquisition program.

Table 1 highlights perspectives, responsibilities and objectives of the executive branch for defense acquisition.

2. Program Management

For each acquisition program there is a program manager with responsibility for executing that program. The program manager must obtain approval from the AE for an acquisition strategy, request a budget, select contractors, manage development contracts, report to the AE and report to congress, and mind a myriad of details. The Program

Table 1: Executive Branch (from DSMC Introduction to Defense Acquisition Management)

Perspectives	Responsibilities	Objectives
<ul style="list-style-type: none"> • Formulate, direct & execute National Security Policy • Patriotism • Personal Ambition • Re-Election 	<ul style="list-style-type: none"> • Sign legislation (President) • Commander in Chief (Pres) • Negotiate with Congress • Make Decisions for Acquisition Programs (Acquisition Executive) • Issue Directives/Regulations • Contract with Industry 	<ul style="list-style-type: none"> • Satisfy National Security Objectives • Balanced Force Structure • Field Weapon Systems to Defeat Threats to National Security • Eliminate Fraud Waste and Abuse in Federal Procurement

Manager (PM) is the key person in the acquisition process for each program. Figure 2 makes this plain. This is the program environment for a domestic defense acquisition program involving only the U.S. While this diagram may appear complex, it is relatively elegant. From this diagram it can be surmized that the PM for a domestic U.S. defense acquisition program is central to program execution.

3. Rules of the Road

DODD 5000.1, DODI 5000.2 and DOD 5000.2-R, hereinafter referred to collectively as DOD 5000, set forth the statutes that apply and define the processes, procedures and guidelines to be used for acquisition of Major Defense Acquisition Programs (MDAPS).

DOD 5000 has evolved. Since 1994 the focus has been to enable streamlined, tailored acquisition while providing a standardized framework to guide all DOD acquisition. The DOD 5000 documents summarize statutory requirements for MDAPs and establish DOD regulatory requirements for MDAPs. These documents provide the single set of guidance for execution of all DOD acquisition. Each program is

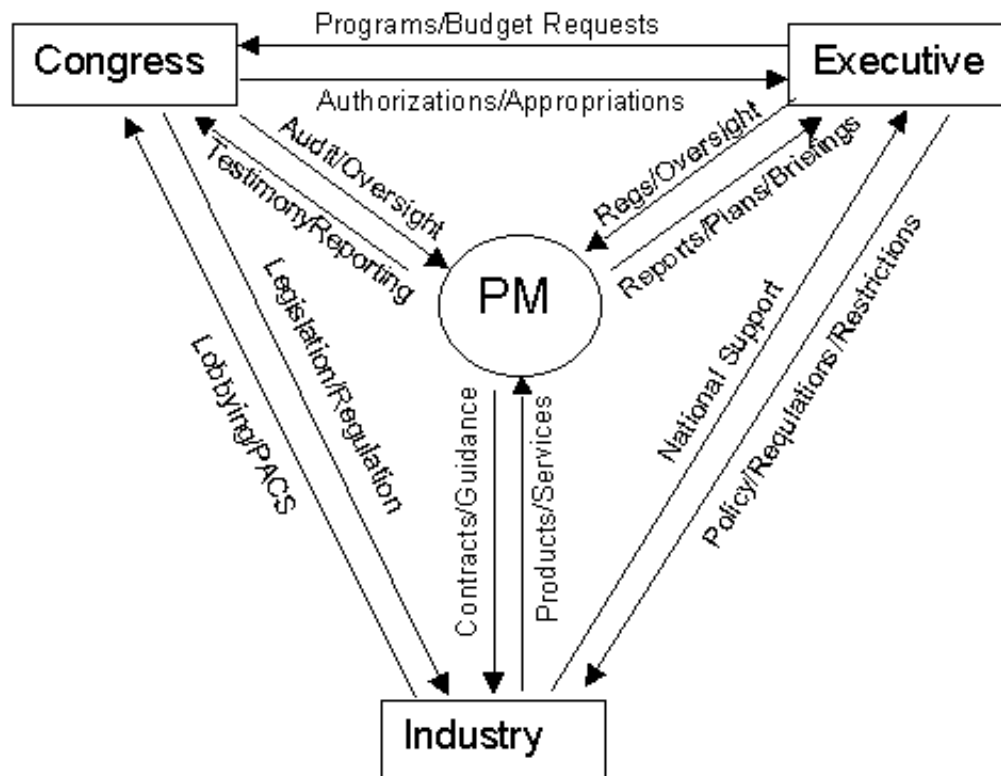


Figure 2: PM Centric Acquisition (from Introduction to Defense Acquisition Management)

expected to develop an acquisition strategy, for approval by the cognizant Milestone Decision Authority (MDA), that establishes how the requirements of DOD 5000 will be met. The overall “cradle to grave” acquisition process is summarized by Figure 3.

System development, occurs primarily following milestone B during the System Development and Demonstration phase (SD&D). Much of the guidance in DOD 5000 applies to TMO.

a. Significant Statutes

While many laws have been written that influence DOD system acquisition, a few that are worth highlighting, because of their influence on Technical Management Oversight. The Clinger-Cohen Act (40 U.S.C. 1427) requires special reporting for information intensive

THE 5000 MODEL

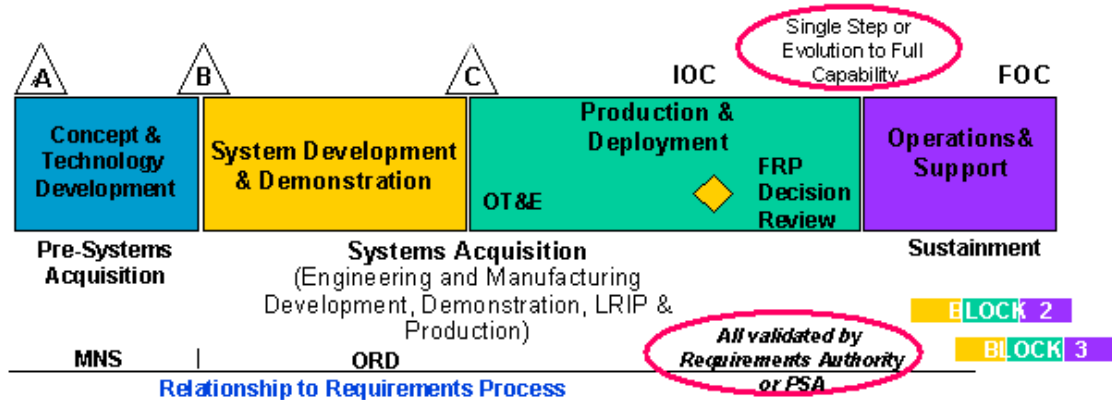


Figure 3: The DOD 5000 Acquisition Model (From DODD 5000.1)

systems and requires coordination in order to ensure development of effective information exchange capabilities. The National Environmental Policy Act (NEPA) (42 U.S.C. 4321-4370d) directly affects system development because of legal constraints placed on the use of hazardous and environmentally damaging substances and materials. Similarly, the Occupational Safety and Health Act (OSHA) (42 U.S.C. 4321-4370d) constrains system design. Legal mandates for independent system testing are contained in 10 USC 2399(b)(1), "Operational Test and Evaluation."

b. Guidance

DOD 5000 regulates the establishment of tailored MDAP acquisition programs and establishes mandatory procedures for MDAPs. There is some ambiguity about what guidance applies to International programs, except for the specific international program guidance. For example, the international program section of DOD 5000.2-R makes the military services responsible to ensure the Operational Requirements

Document (ORD); the Command, Control, Communications, Computers and Intelligence Support Plan (C4ISP); the Test and Evaluation Master Plan (TEMP) and the Acquisition Program Baseline (APB) documents are properly staffed for international programs. The following paragraphs highlight mandatory procedures that have a direct bearing on Technical Management Oversight for MDAPS. To understand the degree of mandate associated with an international program, careful review should be made of DOD 5000 and the legally binding references in the applicable international Memorandum of Understanding.

(1) Program Goals should be well established in an APB including thresholds and objectives for cost, schedule and performance. Consequences for not meeting the APB should be clearly established. Cost As and Independent Variable (CAIV) activity should be performed to enable trade-offs between system requirements, cost and schedule. This activity should be done in close coordination with the system user.

(2) An Acquisition Strategy should be developed early in the program and updated for each subsequent program phase. This document tailors DOD 5000 to each MDAP and is a contract between the Program Manager and the Acquisition Executive that establishes how the program will be executed. Electronic data exchange is described. The program's approach to management of people, funding, risk, staffing, contracting and oversight are described. Special considerations for simulation based acquisition, software development, the technical management approach and business strategy are all described.

(3) The program's approach to Test and Evaluation should coordinate Developmental Testing (DT) and Operational Testing

(OT). DT and OT objectives should be placed in the Test and Evaluation Master Plan (TEMP), which is a required document for all MDAPs. Plans should be established for information technology security certification, interoperability certification, information assurance testing, development of model and simulations that are validated against real test data and anti-tamper verification testing.

(4) Considerations for System Engineering drawn from technical literature are described later in chapter II section C, however, guidance is provided in DOD 5000.2-R that is comprehensive. Considerable guidance is provided for management of technical risk, requirements, open systems design, software development, design for supportability, quality and configuration management.

(5) Other Guidance from DOD 5000.2-R covers topics of information superiority; Reliability, Availability, Maintainability (RAM); interoperability, insensitive munitions, corrosion prevention and control, electromagnetic effects and spectrum supportability, required reviews, ... and so forth.

B. INTERNATIONAL CONSIDERATIONS

1. Overview

The primary source of information for this section is the research report by Catington, Knudson and Yodzis entitled “Transatlantic Armaments Cooperation.” They note that transatlantic international cooperative development of weapon systems during the past 40 years has been done in order to distribute costs for weapon systems development, to leverage technology from partner nations and to improve interoperability among partner systems. These goals are complicated by the conflicting national politics, protection of the industrial base,

protection of technology, national priorities, requirements harmonization, the implementation of the partnership, and culture. The importance of an international Memorandum of Understanding (MOU) that establishes an agreement for the nature and extent of an international MDAP cannot be over-emphasized. Figure 4 summarizes the considerations for an international MDAP that are discussed in this chapter.

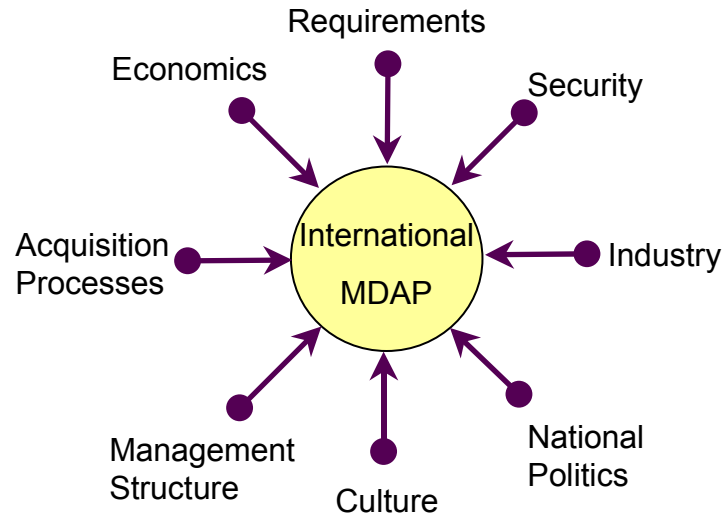


Figure 4: International Considerations

2. Politics

National politics drive conflicting desires of each participant to minimize expenditures while maximizing the local benefit. The desire to minimize expenditures combined with the need for interoperability opens the door to international cooperation. However, the desire to maximize local investment greatly complicates management because balancing of workload must be accomplished. When the concept of noble work-share is established, this complicates matters even more. Then, not only must the workload be balanced, but the work must be seen as meaningful by each partner.

Separate national political processes reduce program stability, because each partner nation must gain political support for funding. The decision processes are different, may not be synchronized, and may be strongly affected by National elections. New Government administrations may require time to establish funding priorities, and they may not agree with the funding priorities of past national administrations. During the time that separate national funding decision processes are under way, uncertainty can be expected. Who knows if program participation by each nation will continue? However, there is a pair of stabilizing influences: The desire for success once started; and an aversion to being identified as the nation that quit. National pride is at stake. However, the nature of the threat changes, war-fighting doctrine or national priorities change, a partner nation may cease to have a need for the system. In that case, political support would probably be unsustainable.

3. Economics

Economics is the foundation that makes programs possible. What often makes international MDAPs economically unique as compared to domestic MDAPS are the agreements for sharing of costs and work, multiple funding decision processes and exchange rates. Multiple national economies influence availability of funds. The general economic health of industry within each country may affect the ability of the countries to participate. Exchange rates may become an issue. If international monetary exchange rates fluctuate over the life of a program, then the countries may pay more or less than expected.

4. Requirements

Harmonizing requirements for an international MDAP is perhaps the most important activity, and it is not an easy process. Nations have

differing interests and priorities. Threat, need date, functions to be performed (mobility, threat detection capability, communications, speed, automation, etc), characteristics (accuracy, display/labeling language, weight, size, transportability, etc.), and required operational environments must be harmonized. National laws and regulations may conflict. Fortunately DOD now mandates the use of performance based requirements and specifications, which make international MDAPs more possible. The streamlining of acquisition through use of commercial standards and performance specifications is gaining favor outside of the U.S. DOD as well as within. This emerging common approach helps as partners harmonize program requirements. Additionally, understanding the needs of the partner nations is essential to making needed compromises.

Capability not needed by one nation will be opposed by that nation in an effort to hold down cost. Capability perceived as important by that nation will be vigorously promoted. The differences must be negotiated, and there is no assured resolution of any difference. One way to address this issue is the creation of national variants with tailored end items built around common core capability. Establishing Key Performance Parameters (KPPs), a set of agreed essential requirements, is important. These KPPs define the potential trade space for Cost As an Independent Variable (CAIV) tradeoffs when test results emerge and as costs become better understood. Agreeing on the time frame for development and the extent of international variants of the core system are important as well.

5. Security

Security for an international MDAP is both collective and individual. The effectiveness of a military system often depends on denying potential adversaries access to system vulnerability information.

Thus, it is in the common interest of the partners to protect system information that may reveal vulnerabilities.

The U.S. may bring technologies into the cooperative effort that it considers to be advanced, and may be unwilling to fully disclose these technologies. Access to some technology may be restricted to “black box” devices where the inputs and outputs are advertised, but the internal design or manufacturing details are not divulged. In the case of advanced computer algorithms, software source code may not be divulged, only the executable code. Partner nations may be uncomfortable with this, however, it should be kept in mind that protection of information even within a one nation development activity is not unusual. For developments involving more than one company, detailed design and process information is often with-held from other companies by the owning company to protect company interests.

The U.S. has policies that establish a security framework for U.S. participation in international MDAPS, including processes for the transfer of technology to foreign entities. The DOD security directives that apply are DOD Directive (DODD) 5230.11, DODD 5230.20 and DODD 5000.39. Technology transfers are governed by the International Traffic in Arms Regulations (ITAR) and DODD 2040.2. Industrial security policy, which the participating companies must follow, is established in the National Industrial Security Operating Manual (NISPOM). The document that will establish security procedures once information is within the program is the Program Security Instruction (PSI), which will be unique to each international MDAP and must be agreed to by all national partners.

6. Management

Historically, cooperative international developments have involved similar management structures, as shown in Figure 5, with variations on

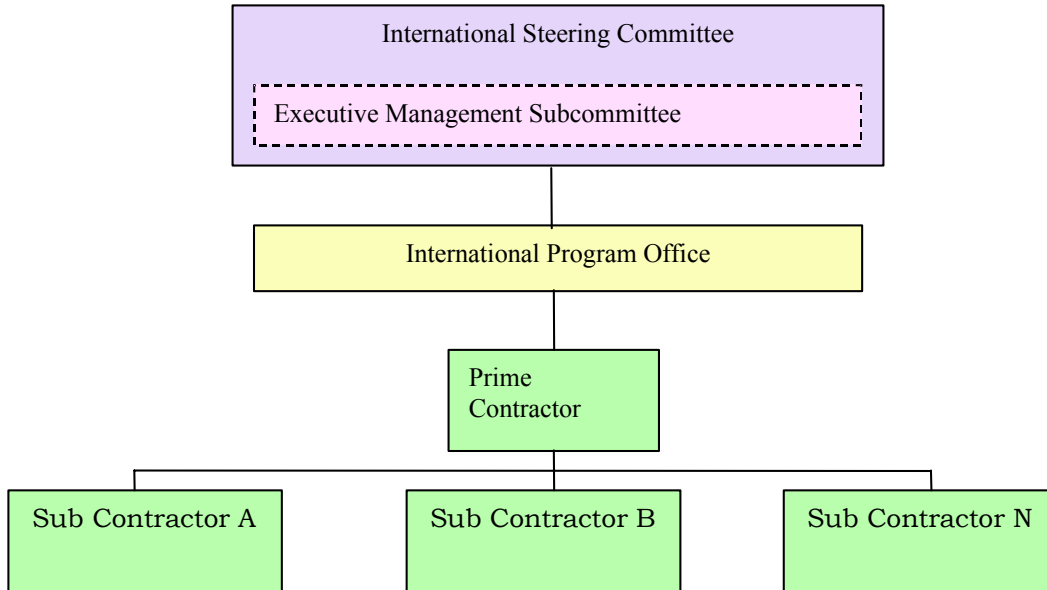


Figure 5: Generic International MDAP Structure

the theme. Typically, an international steering committee, consisting of senior military or civilian decision-makers, oversees the development program. The Steering Committee may or may not employ an executive management subcommittee to coordinate day to day. An international project office will manage the program and a prime contractor will design and build the system, participating in some aspects of development and integration, and managing subcontractor activity.

Within this conceptual management framework, variations occur. In many cases the U.S. provides the largest individual share of funding, but has an equal vote with each other partner on the Steering Committee. In some cases the U.S. has been given leadership for management of the International Project Office (IPO) effort and is responsible for managing the development and coordinating with support provided by partner nations. This approach has proven effective, and

from the point of view of the U.S. is fair when the U.S. provides the largest share of funding. However, the partner nations often prefer to have a more even distribution of responsibilities. In some cases, program leadership is shared or rotated between partner nations. It has also been shown that this approach can be effective. Regardless of the assignment of responsibilities for each nation, the agreements made early are important, because they tend to remain throughout the life of the program.

7. Industry

Industrial arrangements between companies participating in the development and production vary widely for cooperative international development as with domestic U.S. development. The nature of these arrangements will depend on the guidance provided by the partner nations during solicitation and on the industrial agreements that the winning contractor is able to negotiate with partner companies. Many are the possibilities.

8. National Acquisition Processes

The context for an international cooperative development makes a difficult activity more difficult. The development activity must satisfy the authorizing bodies of each participating nation in order for that nation to continue participation. Each partner nation will have a bureaucracy that needs information and demands to be heard. Section A of this chapter highlights the DOD 5000 guidance that affects U.S. programs. It is clear that U.S. laws and regulations must be followed by U.S. leadership in the negotiations to structure an international cooperative development. However, it is not always clear which legal and regulatory requirements must be followed during the execution of an international program, especially if the different participant nations have different legal

and regulatory requirements. Once signed, a Memorandum Of Understanding (MOU) between Nations establishing an agreement for the conduct of a development effort will generally take precedence. The difficulty of satisfying the acquisition processes for the participating nations increases with the number of participants.

9. Culture

Differing national cultures and norms of behavior affect day to day program operations. Early effort is needed to build trust and understanding between participants. This may seem trivial, but may make the difference between whether team members cooperate or fight. Nation A participants may be accustomed to rigid organizational control and individual conformance. Nation B participants may be accustomed to a more relaxed approach. Nation C participants may be accustomed to a greater degree of delegation of authority, ... these considerations apply to any organized activity. However, for international programs, the importance of getting along and working together is even higher because of the difficulty in resolving differences. A problem between two individuals could be interpreted as a problem between two national partners, which ultimately might lead to one or more nations quitting the program. Cultural differences are not only challenges for each individual, but also for each nation's team.

C. SYSTEM ENGINEERING PRINCIPLES

1. Overview

For a major undertaking, development complexity is enormous. Figure 6 suggests the magnitude of the effort. This system engineering review lays the foundation for the TMO framework definition that follows.

This section is not intended as a

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.
"I don't much care where ____" said Alice.
"Then it doesn't matter which way you go," said the Cat.
"____ so long as I get somewhere," Alice added as an explanation.
"Oh, you're sure to do that," said the Cat, "if you only walk long enough."
...
Lewis Carroll, Alice in onderland,,1865

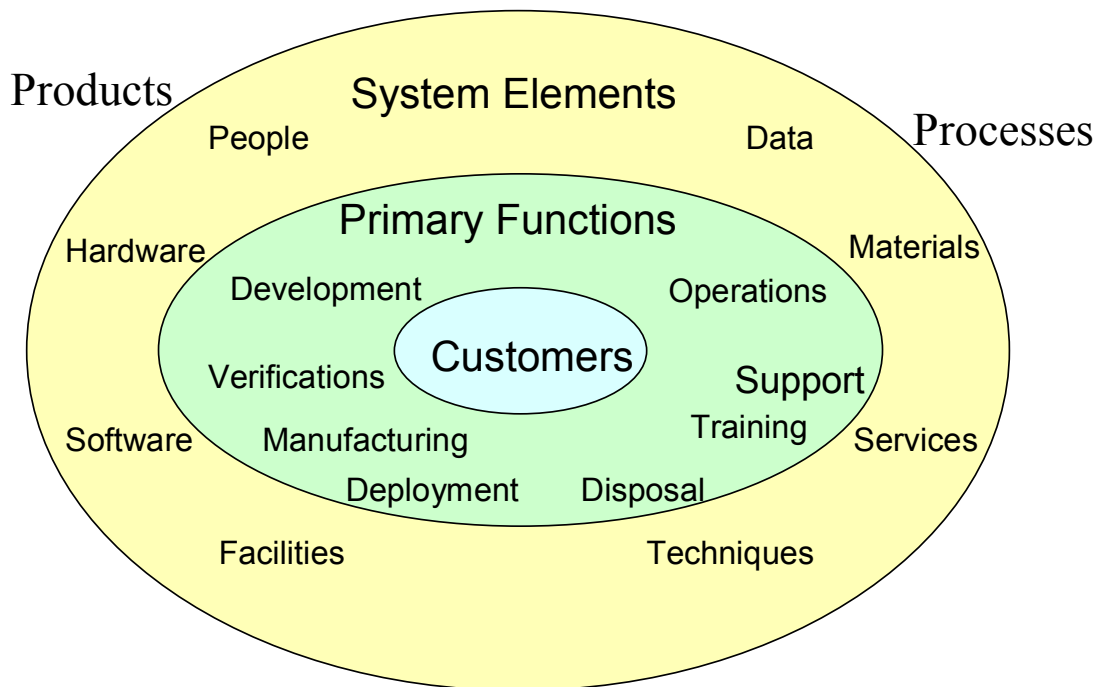


Figure 6: System Engineering Products and Processes (From Orin Marvel Lecture Notes)

comprehensive presentation on system engineering; but rather, it is intended to provide a summary of basic system engineering principles, to support the later material.

2. Development of Complex Systems

System engineering has emerged as a discipline for managing development of complex systems. The evolution of the discipline parallels the advancement of human civilization. Social systems emerged with specialization such as food gathering, hunting, defense, leadership, etc. The building of complex structures, such as houses, palaces, tunnels, pyramids, bridges and weapons resulted in specialization as well. The processes may not have been thought of as system engineering, it was organized human activity in the struggle to survive. Yet, it was system engineering. The methods used enabled development of systems that no one person could build or fully understand. The differences are that now we have generalized the idea of system engineering, documented repeatable processes, increased specialization, and we now have automated tools to help us manage information.

3. Aspects of System Engineering

Table 2 lists 30 aspects of system engineering. For development of complex systems, many people are involved. How they exchange information and make decisions impacts program success.

Table 2: System Engineering Considerations (from Howard Eisner)

1. Requirements: Needs/Goals/Objectives	11. Specification Development	21. Configuration Management
2. Requirements: Mission Engineering	12. Hardware/Software/Human Engineering	22. Specialty Engineering
3. Requirements Analysis/Allocation	13. Interface Control	23. PrePlanned Prod Improvement (P3I)
4. Functional Analysis/Allocation	14. Computer Tool Evaluation and Utilization	24. Training
5. Architecture Design/Synthesis	15. Technical Data Management	25. Documentation
6. Alternatives Analysis/Evaluation	16. Integrated Logistics Support	26. Production
7. Technical Performance Measurement (TPM)	17. Reliability, Availability, Maintainability	27. Installation
8. Life Cycle Costing	18. Integration	28. Operations and Maintenance
9. Risk Analysis	19. Test and Evaluation	29. Operations Evaluation/ Reengineering
10. Concurrent Engineering	20. Quality Assurance and Management	30. Systems Engineering Mgmt (Planning, Organizing, Directing, Monitoring)

4. Evolution of System Engineering

The understanding of system engineering principles has evolved. During the industrial revolution, Edison developed systems using new technologies involving electricity, acoustics and novel materials. During his time there was no recognized system engineering discipline. Yet he had to grapple with the issues embodied in table 2. Edison understood the importance of good communications in industrial research and access to information and materials. A library was central to his laboratory. Also, he was a practical man. He was once heard saying, “The most important part of an experimental laboratory is a big scrap heap.” He understood the value of specialization and independent initiative: “Hell, there ain’t no rules here! We’re trying to accomplish something!” Work at his invention factory took no heed of the clock. He gave workers a sense of shared identification with his goals (Millard). Yet, while Edison may have had an innate understanding of system engineering principles, his homegrown brew of methods was dependent on his personal genius and ability to inspire others. Commonly accepted system engineering standards did not exist.

5. Psychology of System Engineering

System engineering evolved because of a duality: The human desire to survive coupled with human limitations. Studies in psychology have shown that short-term memory is at the root of our creative abilities. However, at one time we can retain only five to seven separate objects in our short-term memory. Long term memory has much more capacity, however, it is slow and much less accurate. These limitations can be overcome by organized cooperative efforts involving specialists.

People are able to know a lot about a few topics, or a little bit about a lot of topics. For example, a neuro-optometrist knows a lot about eyes, the optic nerve and the visual cortex, but is unlikely to know much

about road construction. Knowledge can be deep or it can be wide. This is depicted in Figure 7.

6. System Engineering Standards

System engineering is an organized approach to managing the development of complex systems.

Standardized methodologies are captured in the Electronic Industries Association (EIA) standard IS-632, and Institute of Electrical and Electronics Engineers (IEEE) standard P1220. These standards have their genesis in DOD Standard 499. The definition of system engineering from each of these standards is described in Table 3.

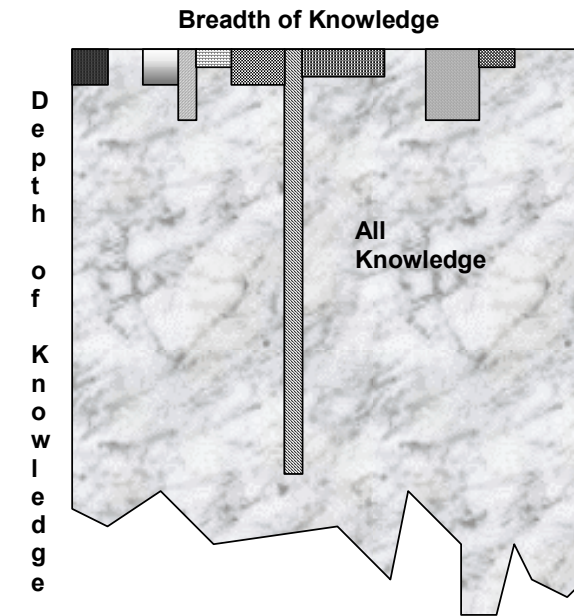


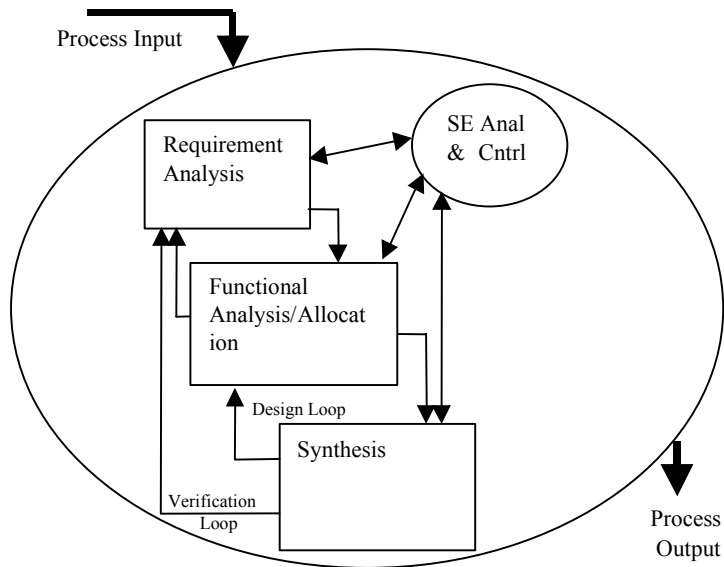
Figure 7: Knowledge (from Jeffrey O. Grady)

Table 3: System Engineering Definitions (From MIL STD 499A, EIA Standard IS-632 and IEEE Standard P1220)

MIL STD 499A, Engineering Management (Now Cancelled)	EIA Standard IS-632, Systems Engineering	IEEE P1220, Standard for Application and Management of the Systems Engineering Process
A logical sequence of activities and decisions transforming an operational need into a description of system performance parameters and a preferred system configuration.	An interdisciplinary approach encompassing the entire technical effort, to evolve into and verify an integrated and life cycle balanced set of system people, products, and process solutions that satisfy customer needs.	An interdisciplinary, collaborative approach to derive, evolve and verify a life cycle balanced systemsolution which satisfies customer expectations and meets public acceptability.

7. Department of Defense View

Figure 8 depicts the DOD system engineering process diagram. In this diagram, a function called “SE Anal & Cntrl” is segregated from the other activities, intended to emphasize that analysis and control apply to each of the three system engineering activities. Verification is shown as a loop between “Synthesis” and “Requirements Analysis.”



**Figure 8: DOD System Engineering Process
(From DSMC System Fundamentals)**

Table 4 describes the system engineering activities shown in Figure 8.

Table 4: System Engineering Definitions (From DSMC System Engineering Fundamentals)

Requirements Development Define Requirements Ensure Completeness Logical Completeness Constraints Identified (such as environment) Functions Identified Applicable Standards Identified Ensure Testability	Functional Analysis and Allocation Decomposition of Functions to lower level Define a functional architecture, which associates the lower level functions Develop Interface Requirements for the functions
Synthesis Transform the functional architecture into alternative physical architectures Define candidate objects (physical elements) for the system Do Trade studies to select the preferred physical architecture and objects Define the physical interfaces Design the System	Validation and Verification Validation Requirements are correct and achievable Requirements have been satisfactorily allocated Verification Design satisfies the requirements System is implemented according to the design

8. Relationship of Requirements to Test

Dividing the system engineering process into sub-processes provides a means to partition the larger process into distinct, manageable inter-related processes. The V diagram, Figure 9, emphasizes the relationship between requirements and test activities. Looking at this diagram it is easy to visualize the effect of an error in system requirements, increasing the need to do up front work, such as modeling and simulation, to ensure system requirements are correct and achievable.

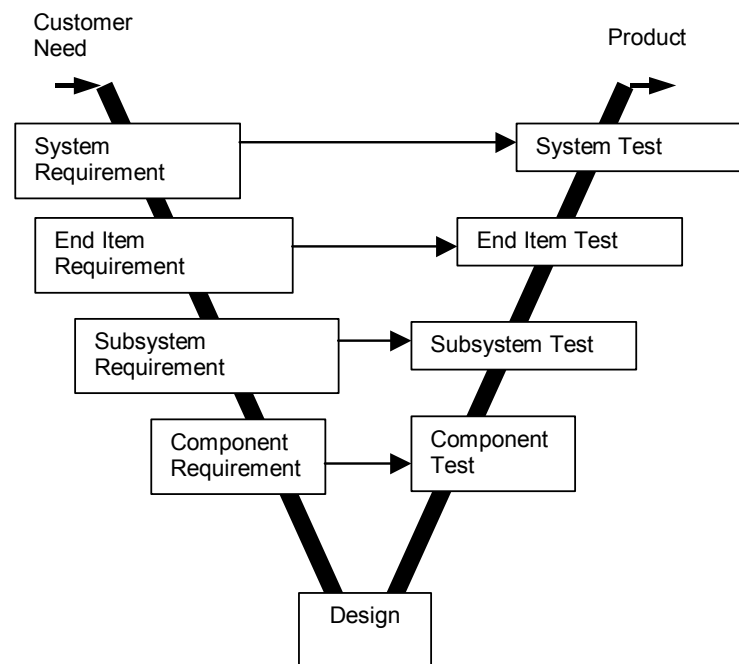


Figure 9: System Engineering “V” Diagram (From Orin Marvel Lecture Notes)

9. Early Commitment of Resources

The Committed versus Actuals diagram, Figure 10, highlights the effect of requirements and design decisions made early in a project. What this diagram is showing is that decisions made early affect the work (and thus the cost) to be done later. This provides further motivation to ensure the requirements are reasonable before initiating design and fabrication.

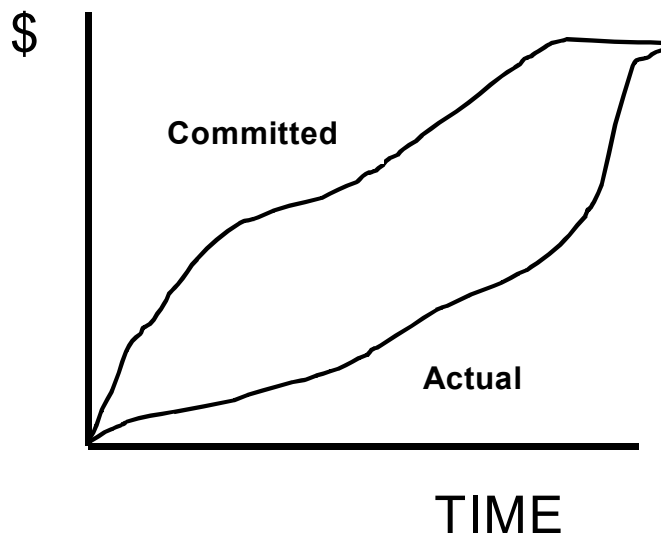


Figure 10: Committed vs Actuals (From Orin Marvel Lecture Notes)

10. Spiral Development

For any system, improvements can be made over time. This applies to all system aspects: Requirements, design, fabrication, maintenance, training, etc. Sometimes it is desirable to plan for improvement over time, especially if the system being developed is unfamiliar. Figure 11 depicts a spiral development process where multiple iterations of system development occur. The iterations are planned in advance, in recognition that it will not be possible obtain the best solution the first time through the development cycle.

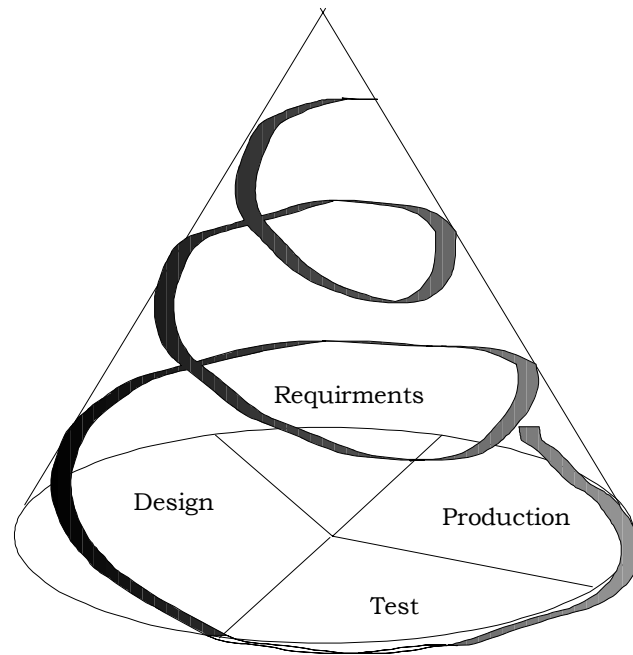


Figure 11: Spiral Development (From Jeffrey O. Grady)

11. Five Habits of a Successful Project

Development of a major system is difficult, uncertain, requires creativity to overcome risk, and requires constant focus on essentials. Five habits of a successful project, based on lectures from Dr. Orin Marvel at the Naval Postgraduate School and writings from Grady Booch are listed in Table 5.

Major system development involves complexity that must be managed. The development team should work to one integrated set of requirements and processes. A System Engineering Management Plan (SEMP) should be developed to form the basis for an overall project plan and integrated master schedule. Risk should be evaluated and resources assigned accordingly to investigate alternative solutions. Before large investments are made to develop complex solutions in hardware and software for the system or any level of subsystems, confidence should be gained through analysis, modeling, simulation and prototype

Table 5: Five Habits of a Successful Project (from Orin Marvel at the Naval Postgraduate School and writings from Grady Booch)

1. A ruthless focus on the development of a system that provides a well understood collection of essential minimal characteristics;
2. The existence of a culture that is centered on results, encourages communication and yet is not afraid to fail;
3. The effective use of modeling and simulation;
4. The existence of a strong architectural vision;
5. The existence of a well managed iterative and incremental life cycle.

development. Technical Performance Measures (TPMs) should be established early, to be used as metrics during the development effort, to track how well the design satisfies the requirements.

12. Organization

The structure of a development organization, and communication processes within the organization are important to successful system development. Eisner suggests that a project organization should be headed by a project manager with the key subordinates of Chief System Engineer and Controller. The program manager has overall responsibility for successful execution of the program, but his focus is primarily outward, with the goal of ensuring that customer needs are met. The role of the chief system engineer is to coordinate efforts of all the engineers in the project to ensure that an optimal technical solution is achieved. The role of the controller is to manage the business of the project such as contracts, schedules and finances. He calls these three key project individuals the triumvirate, with overlapping responsibilities (Eisner pp 14-16, 24). At lower levels, a program may be organized along product lines or by functions. Participants may be dedicated to the

project or matrixed from a functional organization. In any case, there is a mapping of skills to the defined system engineering process and the defined tasks. For complex programs, formal coordination will be necessary. However, informal communications is often the best way to foster creativity and innovation.

System engineering involves a coordinated set of processes with engineering practitioners from a multitude of disciplines. For a large project, no one person can know everything there is to know about the project. This makes establishment of a clear system engineering process imperative. Standards in use today that define tailorable processes for application to various programs. Current standards are based on previous military standards. Military standards for system engineering have been superseded by commercial standards. Table 6 lists several system engineering standards and texts that are applicable to development of complex systems.

Table 6: Widely Used System Engineering Standards and Texts

- | |
|--|
| <ol style="list-style-type: none">1. EIA Standard IS – 632 System Engineering2. IEEE P1220 Standard for Systems Engineering3. MIL-STD-961D Defense Specifications4. System Engineering Fundamentals, Defense Systems Management College (DSMC), 19995. System Engineering Management, Benjamin S. Blanchard, 19986. System Architecting, Eberhardt Rechtin, 19917. System Validation and Verification, Jeffrey O. Grady8. Strategies for Real Time System Specification, Hatley and Pirbhai |
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III. TECHNICAL MANAGEMENT OVERSIGHT FRAMEWORK

A. TECHNICAL MANAGEMENT OVERSIGHT

This chapter defines Technical Management Oversight (TMO) and the framework that will be used in chapter IV to characterize TMO for several international Major Defense Acquisition Programs (MDAPs).

TMO is technical management, from the customer perspective. It helps the customer to get his/her “money’s worth.” Creating a new system requires partnership between the prime contractor engineers and the customer TMO. The TMO activity defines the work to be performed and the system to be built, then certifies that the system developed meets the needs of the Users. The prime contractor, with direct control of scientists, engineers and technicians, will create a system where no system existed before. For complex programs, risk may be shared and there may be a degree of collaboration between the customer and the prime contractor. However, the prime contractor remains responsible for producing the system, and the TMO activity remains responsible to verify that the technical performance requirements have been met.

Looking to prime contractor development, TMO involves system engineering, but not the same system engineering that is done by the prime contractor. Section B of this chapter describes a TMO framework is be used to highlight TMO activities that are central to Major Defense Acquisition Programs (MDAPs) and that may be used for understanding TMO for international programs. Looking outward, the international customers must be convinced of program success. From the U.S. perspective, the U.S. acquisition process must be satisfied in order to continue into the next acquisition phase.

B. FRAMEWORK

A framework for describing TMO is shown in Figure 12. The framework includes the U.S. acquisition review process in the context of an international program. Although equally important, the acquisition

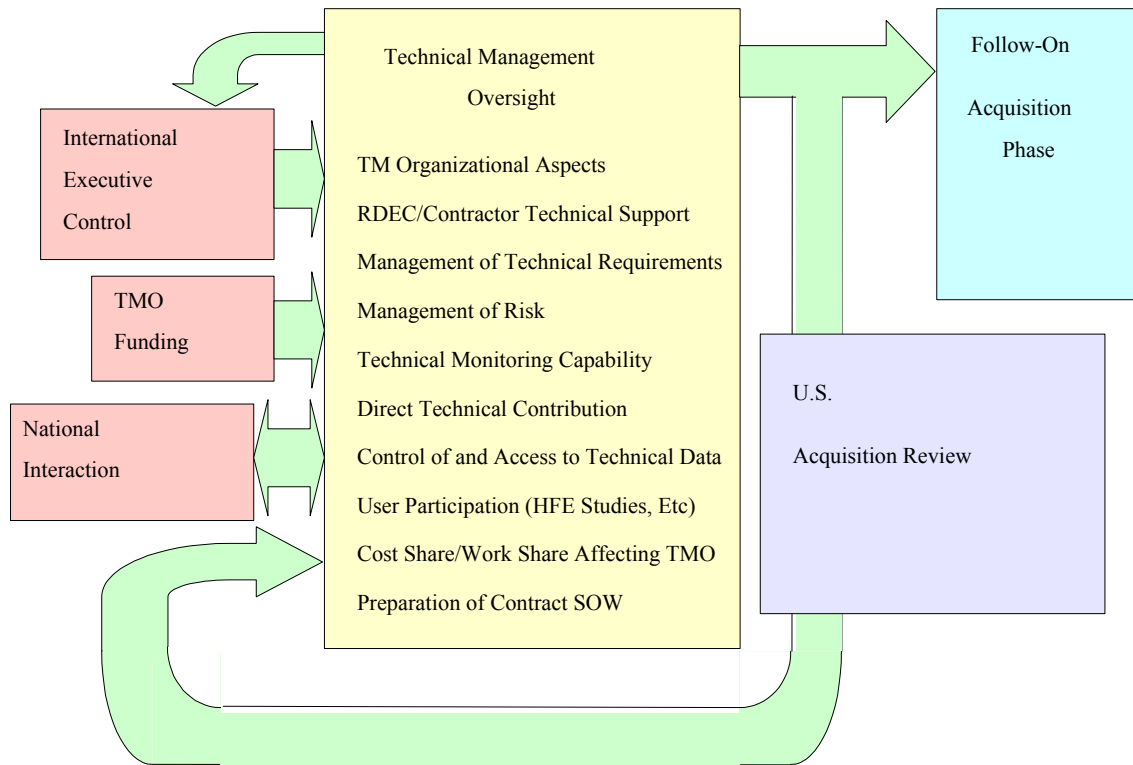


Figure 12: International Technical Management Oversight Framework

review processes for partner nations is not included as part of this thesis. This limitation allows focus on the U.S. aspects of TMO for an international MDAP and limits the scope of the thesis.

C. TMO CONSIDERATIONS

1. TMO Organizational Aspects

TMO Organizational Aspects represent the external and internal organization considerations that affect TMO for the activity. Externally, the relationship of the International Program Office to its national

sponsors is described. Internally, the IPO organization structure is described.

2. Research Development and Engineering Center (RDEC)/Contractor Technical Support

RDEC/Contractor Technical Support is the technical support obtained from external sources to help develop system requirements, to help develop contract statements of work, to evaluate contractor performance, to evaluate technical suitability of specifications and designs, to facilitate transfer of new technologies to help the customer be a smart buyer. This technical support is independent of the prime contractor. Technical support may be obtained from an agency of a partner nations, from a contracted source, or a combination of these sources. This support provides an extension of the program management activity. The TMO framework includes technical support because technical support plays a large role in the execution and oversight of U.S. MDAPs, and it is important to understand the uniqueness of technical support for international MDAPs.

3. Effective Management of Technical Requirements

Effective management of technical requirements is critical to all acquisition programs. For a domestic U.S. MDAP, program requirements begin with the User's ORD. Typically, a U.S. Program Management Office (PMO) will translate the ORD into a contract technical requirements document that becomes part of a development contract. For international MDAPs, the process for management of top level requirements will vary from program to program.

4. Management of Technical Risk

Management of technical risk is critical to all acquisition programs. In simple terms, every opportunity requires identifying anything that can cause a program to fail and then doing something about it. In practice, risk management may involve selection of contractors with proven track records for successfully developing systems, identification of technology risks, establishment of Technical Performance Measures (TPMs) for monitoring technical risk, identification of process risks, establishment of process metrics, and monitoring of risk throughout the program. The manner that any program manages technical risk will have a large impact on the success of a program that involves significant technical risk.

5. Technical Monitoring Capability

The technical monitoring capability of a program office will impact the ability to effectively manage a program. It has been stated for control systems that you cannot control what you cannot measure. A “good” contractor will have internal controls and be able to manage effectively. however, as long as people have self interest, we should not assume the contractor will look out after Government/International Partner interests. Some level of technical monitoring is necessary.

6. Direct Technical Contribution

There are times in a program when a Government/IPO person must make a direct technical contribution. This may occur in a variety of circumstances. If a requirement cannot be met, a Government/IPO engineer may need to help identify an achievable and meaningful requirement. The Government/IPO engineer may be aware of technologies that may provide solutions to intractable problems. If the system must interface with other systems, the Government/IPO engineer

may have to help work out a mutually agreeable change to an existing interface. In some cases the Government/IPO engineers may be in a better position than the contractor to identify existing solutions that can be either directly incorporated into the MDAP or modified and included, leading to cost savings. Government/IPO review of proposed designs may identify flaws based on experience with other systems.

7. Control of and Access to Technical Data

Effective control of and access to technical data by contractor/IPO/ Government personnel is important to the success of the program. Without configuration control, any MDAP involving millions of components and millions of software lines of code is a disaster. For the purpose of configuration management, a computer based technical data repository may be used with clearly defined access and change authorizations. A sound configuration management plan is essential.

Another aspect related to control and access to technical data has to do with company or Government ownership of data. A company may consider certain data to be competition sensitive and may not want to share that data. Governments may consider certain data to be militarily sensitive, and may not want to share the information with other countries for fear of losing tactical or strategic military advantage.

Different approaches can be taken to sharing country or company proprietary data. One approach is to allow open access to all information by all program personnel (assuming a reasonable need to know). If multiple companies are involved, this might not be palatable because of company desires to protect proprietary information. Sometimes the U.S. is reluctant to share all technical details with its partners in areas where the U.S. has a perceived significant technological lead. Contractors are often reluctant to share information with the Government/IPO, perhaps

due to fear of Government interference. How effective an international MDAP is at sharing necessary information can have a large influence on the success of the program.

8. User Participation

User participation may be desired during the early design stages of an MDAP, particularly for defining details of Human System Integration (HSI) interfaces. The system must be designed to meet the extremes of human weight, size, shape, strength and intelligence that is required. HSI studies are often useful to help determine optimal switch configurations, responses to audible alert signals and computer display appearance.

9. Cost Share and Work Share

In addition to affecting prime contractor work plans and allocation of resources, cost share and work share may have an effect on TMO. This may affect access/utilization of independent Hardware in the Loop and other simulation facilities, interoperability facilities, and test facilities. This may also affect access to technical support.

10. Preparation of Contract Statements of Work (SOW)

Preparation of Contract Statements of Work (SOW) is a primary responsibility of the technical management activity within many program management offices. The resulting SOW becomes the effective Bible for all technical work performed under the contract by the contractor and for TMO interactions with the contractor. Required deliverables and activities will affect the nature of TMO for the duration of the contract.

D. PROGRAM FEEDBACK AND INPUTS AFFECTING TMO

1. International Executive Control

International executive control is accomplished by an international board of directors consisting of senior members of the acquisition community of each nation. Collectively the group will be chartered to oversee the IPO and make executive decisions that are outside of the authority of the IPO. Although not fully accurate, this international executive control activity has been likened to the DOD, for an international program.

2. TMO Funding

For the purpose of this paper, TMO funding is the funding for the IPO engineering staff, the funding for IPO technical support, and the funding applied independently by each partner nation for engineering staff and for technical support.

3. National Interaction

National interaction is the interactions between the IPO and the national authorities and bureaucracies. Although figure 5 suggests an isolation of the IPO from international processes, coordination must occur between the IPO and the host nations. Requirements must be agreed upon. Changes must be coordinated. Test facilities must be arranged. Contract SOWs must be developed and agreed upon. The degree to which each nation becomes involved in these activities external to the IPO will be determined by each nation, led by the respective steering committee member.

4. U.S. Acquisition Review Prior to the Next Program Phase

For continuation of an MDAP, there must be a U.S. Acquisition Review Prior to the Next Program Phase. This applies to international

MDAPs as well as domestic MDAPs. What is different between an international MDAP and a domestic MDAP is the tailoring of DOD 5000 requirements. The mandates of an international MDAP are determined by the international Memorandum of Understanding (MOU), which is developed considering the national laws and regulations of all partner nations. DOD 5000 does not necessarily apply! However, for U.S. participation in an international MDAP to continue, a decision must be made to continue. DOD 5000 is intended to be tailored, however, the U.S. DOD acquisition community does not have a lot of experience with international programs.

IV. TMO FRAMEWORK APPLIED

A. HAWK

Information about the HAWK program has been primarily obtained from an interview with Mr. John Robins who was the civilian Deputy Program Manager for Hawk. Extensive excerpts have been made from this interview. While this may not be normal practice, Mr. Robins words speak for themselves.

1. Overview

HAWK is an Air Defense System first developed by the U.S. Army in the 1950s and then sold to and or produced by more than 22 countries worldwide.

Figure 13 depicts HAWK missiles on a HAWK launcher.

Although the U.S. Military no longer uses HAWK, the system is still in use by other

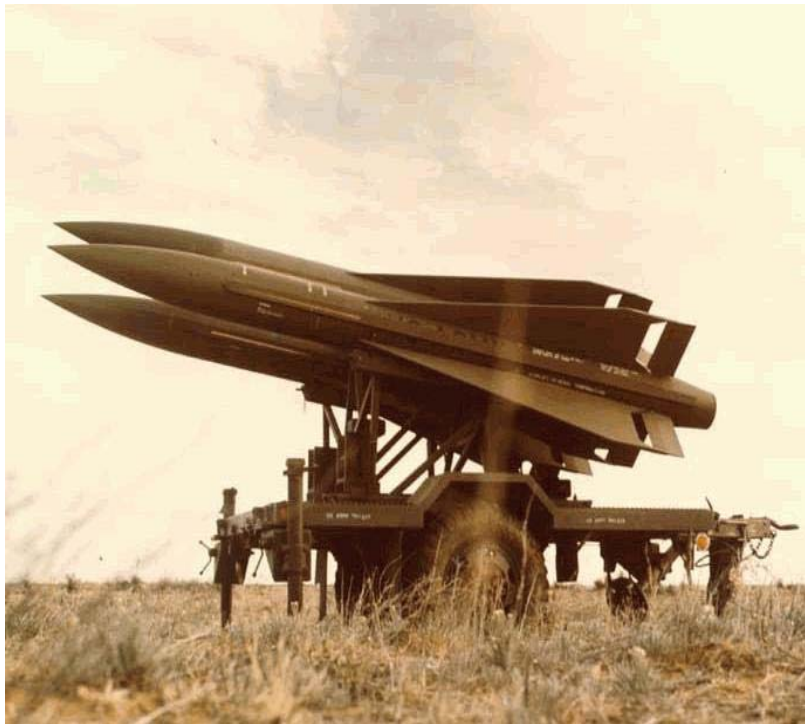


Figure 13: HAWK Missiles (from <http://www.raytheon.com/es/esproducts/dsshawk/dsshawk.htm>)

countries. Key components of HAWK are continuous wave and pulse acquisition radars for low to medium range target acquisition; a

command post for Command and Control (C2) functions, communications and data processing; the HAWK missile; and the launcher. The HAWK system has been involved in conflicts during the last several decades including the Cuban Missile Crisis, the Vietnam War, the 1967 and 1973 Arab-Israeli wars and the Persian Gulf war. Threat targets include fixed wing aircraft, rotary wing aircraft, cruise missiles and short range ballistic missiles (<http://www.raytheon.com/es/esproducts/dsshawk/dsshawk.htm>).

2. Application of the TMO Framework

a. TMO Considerations

Table 7 captures the TMO framework elements for HAWK.

Table 7: HAWK TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	HAWK was developed by the U.S. Army and was later sold to other countries as a completed product or as a data package that would enable foreign production. U.S. project office personnel coordinated with foreign counterparts for sales and setting up production lines, The HAWK PM office was staffed with U.S. personnel.
2. RDEC/ Contractor Technical Support	HAWK technical support included in-house technical support from the Government Program Management Office (PMO), from the Army Missile Command (MICOM) RDEC and from expert technical consultants.
3. Management of Technical Requirements	Stable requirements and design were important for the HAWK program, especially after the beginning of international co-production and international sales. An effort was made to minimize change of the international technical data package that was a directly result of difficulties managing change in an international environment.

Table 7: HAWK TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
4. Management of Technical Risk	<p>Management of Technical Risk for HAWK was affected by international program participation in that when technical problems were discovered, there was a danger of international finger pointing to assign blame for any particular problem. When problems were discovered, the U.S. State Department might get involved and the process of identifying the problem and subsequently solving the problem might become clouded in international politics. Management of technical risk was more difficult because of the additional external scrutiny resulting from the international participation.</p>
5. Technical Monitoring Capability	<p>Technical Monitoring Capability for HAWK was not overtly influenced by international participation, because the U.S. HAWK development activity did not involve international participation. The TMO activity within the U.S. HAWK PMO monitored contractor performance independent of international considerations. Use was made of internal HAWK PMO technical support, the RDEC, and if warranted, independent expert technical consultants.</p>
6. Direct Technical Contribution	<p>During production, a conscious effort was made to minimize change to the international technical data package because of the concern for upsetting a fragile relationship. This had an effect on any contributions made by TMO personnel. However, during development, the direct technical contributions of TMO personnel were not influenced by international considerations. The goals of TMO were as follows:</p> <ul style="list-style-type: none">(1) Ensure users requirements are clearly stated in a system spec(2) Monitor the performance of the contractor development effort with intermediate technical milestones(3) Do root cause analysis when a problem is discovered Don't let the contractor just keep testing and trying to fix the problem until the problem is fully understood.

Table 7: HAWK TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
7. Control of and Access to Technical Data	Control of and Access to Technical Data was not an issue for HAWK development. Export decisions were made regarding the technical data package for independent international production and export of the completed HAWK systems. Export decisions also had to be made regarding individual HAWK upgrades. However, because the development activity was under the sole control of the U.S. Army, Foreign Release of information from other systems or involving advanced research or detailed algorithms was not required. When upgrades were made as a result of sensitive intelligence information, the system upgrade was developed, perhaps a vulnerability was eliminated. A system upgrade was published, and customers could buy them, however, nothing was published identifying the technical details of the change, and in the case of vulnerability related changes, nothing was published describing the vulnerability that was being addressed. Thus, the problem of obtaining approvals to release information was minimized by limiting the information released to the minimum necessary to use the system or to manufacture the system.
8. User Participation	User Participation for HAWK development involved the U.S. Army user, and there are no international considerations for HAWK user participation.
9. Cost Share and Work Share	Cost Share and Work Share did not become an issue for HAWK development because HAWK was developed by and for the U.S. Army. When upgrades were developed after international production and sales had begun, HAWK owners were given opportunity to purchase the upgrades and to provide funding to create the upgrade (as in the MTBF upgrade of the radar described earlier).
10. Preparation of Contract SOWs	Preparation of Contract Statements of Work (SOW) did not involve international negotiations or special international considerations.

b. TMO Program Feedback Considerations

Table 8 captures the TMO Program Feedback framework elements for HAWK.

Table 8: HAWK TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	International Executive Control did not apply to HAWK.
2. TMO Funding	There were no international considerations for HAWK development TMO funding. The HAWK PMO was managed by U.S. personnel and TMO personnel were U.S. people.
3. National Interaction	National Interaction for HAWK was limited to coordination related to purchasing of complete HAWK missile systems, the technical data package and/or individual system upgrades. There were no joint decision processes that were dependent on agreement of all parties to move forward with the program. There was pressure to minimize change to the HAWK technical data package, which minimized even further the international coordination required.
4. US Acquisition Review prior to next phase	U.S. acquisition review for HAWK was consistent with other U.S. managed programs. This was possible because the HAWK program was controlled by a U.S. PMO and the HAWK program was U.S. controlled.

3. Elaboration

a. Example: The Value Of HAWK Technical Support

When serious technical problems arise in a program, often the contractor, TMO personnel and perhaps even RDEC personnel are too close to the problem or lack the expertise to establish the root cause of the problem. Sometimes it is necessary to bring in outside consultants. At key points in development and during production the cost may be easily justified. Making the right technical decision may have a major influence on capability and cost through the life of the fielded system and a delay in production will be costly. An experience highlighting the importance of outside technical consultants and good TMO analysis involved HAWK missiles that exploded prematurely during test firings due to faulty rocket motors.

Successful HAWK production had been ongoing for several years. HAWK was at maximum production. There were 22 countries involved in production or as buyers. Japan was co-producing and NATO had a big co-production group.

They were in production on their own. Others were buying from us. Lord knows, Iran had more HAWKs than we did! Now, when we discuss HAWK, we are talking about more than just the system. There are training facilities and test facilities, and the who thing. At one time 60% of the people at Redstone worked in some way on the HAWK program. Aerojet had come up with a HAWK motor which is real clever. It used a case bonded propellant that is cast in one piece, and it worked! All around the world we were producing thousands per month. During lot qualification testing at Aerojet, one blew up. It was determined that the problem was related to de-bonding of the propellant. The contractor wanted to just scrub the lot and produce another without further analysis, but we said no, let's look at another lot. ... We had the same problem with the other lot. We immediately froze the lots we considered suspect.

Now, you've got 22 countries involved, including the NATO consortium and they are saying, 'It's your fault, you have changed the technical data package.' We are talking about lots of motors, We had the same problem of de-bonding! We then froze the lots we thought were suspect. Now you've got 22 countries including the NATO consortium. and they are saying, ... 'It's your fault. We are using your technical data package and You've changed the data package.' Then, next thing you know, their missiles start blowing up. So it was our fault. We are talking about lots of motors, lots of people, lots of nations. You get the state department involved.

This is a little problem, if you only had the U.S. involved. You'd get in and work the problem. It's a good problem to solve. But when you get the state dept. involved, you don't have time to swat the knats that are going around. Well, you know, we get back to basics here. There is no sense in hacking on this thing until we find out what the problem is. Of course Aerojet already had a fix. We said, no, were going to introduce you to a subject called root cause analysis. You may say 'that's ridiculous, . I can take you the Raytheon, Aerojet, Lincoln, Vought, just about every contractor I have dealt with and they are all the same. I mean, it's their nature, [they want to jump to the solution before understanding the problem.] Anyway, we put a root cause team at aerojet. And I said, one of the people we want to find is a chemical engineer who has worked there for a while, but who is retired. I talked to the president of Aerojet, and he agreed to help. You know the Navy used this motor too. I

said, 'you don't know where the end of this thing is.' Fortunately in HAWK we had the production lots bounded that we thought were affected. Well, we found this fellow and we put him on our root cause team. We took our best engineers and put them on the team. The review team came in as often as needed to say how they are doing and their status and what they new and presented the information. This older fellow says, 'Where did you get that data?' 'We got it from so and so down in Aerojet.' 'Don't believe him, he's not trustworthy.' It turned out, the source of the data was giving bad data! And we went and found out that this guy had and changed a process. ... Now he went in and changed the process for bonding, and made that sucker de-bond. His procedure wasn't written up. He just went on the line and changed it. It was legal, but not documented. He never checked it out, but he changed the process. We found that out and we made a motor with that process and it blew up. We made one with the original process and it didn't blow up. The original problem was solved (June 21, 2001 Interview with John Robins) .

b. Example: International Interaction

There were other problems with HAWK missiles blowing up. Overseas, the international co-production teams needed help identifying their problems. Additional international considerations for use of technical consultants emerged. As the example continues, it becomes clear that for programs involving international participation, it is important to respect national pride and the uniqueness of different cultures.

... and so we then sent the team of people overseas to find out why they were having problems. We sent our consultants over there, with an explosives expert, one who gets involved when cotton gins blow up and things like that. He went where the French were making the motor. So we went in and said we'll find out what's going on. Understand that this motor needs to be made in an environmentally controlled facility. This whole motor de-bonding problem is related to moisture. And you know how sensitive the French are and the kind of courtesy and diplomacy you need in dealing with these people. Well, consultants don't worry

about these things. You ask them to see what the problem is, ... I'll never forget, we almost had a war over there. This group went in to check this facility that is supposed to be environmentally controlled, and they look, and, ... in the exit interview, the on site people and the managers are informed about the findings. The consultant said, 'how in hell can you say this is environmentally controlled, I saw a rat come through that door!' There were gales of silence from Europe. We went for 3 years and never made a change in the technical data package because of that. Because if there was any change in the technical data package they would say 'it is your problem' (June 21, 2001 interview with John Robins).

c. Example: Direct Technical Contribution

An example of a direct technical contribution on the HAWK program from TMO personnel is described below:

In the HAWK program, they had a radar. I was new on the program. I wanted to know, what is the worst Mean Time Between Failure (MTBF) part. What is the highest repair part cost. In HAWK the radar to be operational 24 hr day 360 days per year, with a 27 hour MTB! Those people [the soldiers] were in trouble, struggling to make this thing keep working. We considered initiating a value program. The HAWK radar is a wonderful piece of equipment, with tubes, that was impossible to maintain. We spent as much international money as we could get in an effort to improve the MTBF to 150 Hours. We put up both international money and US money to develop the improvement. One of the quantified Mile Stones we established was 'You will make 3 of these. You will take parts of A, B and C and exchange the parts and make them work.' Raytheon was able to make the first system work as required with some special effort. They were able to make the second system work too. However, it became apparent that fundamental difficulties were being encountered that were not being solved. It was not possible to interchange the parts of the different systems and expect them to operate. We sent two of Dr. McCorkle's young radar engineers from the MICOM RDEC, Mike McFahee and George O'Reilly, to monitor the development activity. They were young, but they were good. I knew there would be technical problems [improving the MTBF], I just

didn't know where they would be. We had high power tubes near low power sensitive electronics. I said, 'I smell something bad going on down there, will you go and see?' They came back and said, with a lot of tweaking they got one to work, then with even more tweaking they got the second unit to work. They said 'There is not a snowballs chance in hades they will be able to swap those parts and make them work.' But the contractor wouldn't admit it, because we're talking a lot of money. The contractor did not want to hear about it. I told them, talk to my guys, and if they are wrong, convince them. Listen to them too. ... Next thing I know, Raytheon came and tried to convince me. But it was just handling. I told them, 'you've got a quantified milestone that requires you to be able to interchange the parts.' Well they went to the MICOM commanding general, and to the Office of the Secretary of Defense (OSD), ... but I had my experts that I believed. The Raytheon guys look down on you but they don't help. This was around Christmas time. I issued a stop work order. Raytheon had never been subject to a stop work order. They said, 'You can't do that.' I said, talk to the contracting officer. You've got 90 days. They said, 'What can we do?' Well, they called in Peter Swerling, who invented Swerling 1 and Swerling 2 for radars, a famous radar person. But the best were McCorkle's guys. The fact is, they even have their own company now called Phase 4. They found the problem and suggested how Raytheon could fix it. Raytheon had 90 days to fix it and they did. We were close to terminating. But we got a radar that had 175 hr MTBF (21 June, 2001 Interview with John Robins).

B. ROLAND

Information about the ROLAND program has been primarily obtained from an interview with Mr. John Robins who was the civilian Program Manager for ROLAND. Extensive excerpts have been made from this interview. While this may not be normal practice, Mr. Robins words speak for themselves.

1. Overview

Figure 14 depicts the firing of a ROLAND missile. The US ROLAND missile is a short range, low-altitude, all-weather, Army air defense artillery surface-to-air missile system which is based upon the Franco-German ROLAND III missile system.



Figure 14: ROLAND Missile Firing (from <http://www.redstone.army.mil/history/roland/summary.html>)

2. Application of the TMO Framework

a. TMO Considerations

Table 9 captures the TMO framework elements for ROLAND.

Table 9: ROLAND TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	The U.S. ROLAND program was a production program that was based on a European system, ROLAND III. ROLAND III was developed by a consortium of European countries. Compared to the HAWK program, ROLAND was a reverse situation. At the time the U.S. became involved, the European ROLAND office included six European countries headed by a French general.

Table 9: ROLAND TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
2. RDEC/ Contractor Technical Support	RDEC/Contractor Technical Support included in-house technical support from the Government Program Management Office (PMO), from the Army Missile Command (MICOM) RDEC and from expert technical consultants.
3. Management of Technical Requirements	Hughes and Boeing, had to obtain the technical data package for the ROLAND air defense system and then integrate ROLAND with U.S. Honest John Trucks, which did not initially satisfy the requirements for ROLAND.
4. Management of Technical Risk	Management of Technical Risk for the U.S. ROLAND program was focused on the implementation by U.S. contractors of technology developed in Europe. However, some technical aspects of the system had to be improved in order to improve reliability and simplify the use of the system. One of the risks had to do with the reliability and calibration of the radar. This risk was uncovered during user testing.
5. Technical Monitoring Capability	Technical Monitoring Capability for ROLAND was not overtly influenced by international participation, because the U.S. ROLAND development activity consisted of U.S. contractors producing an existing system from a technical data package supplied by the European consortium. The TMO activity within the U.S. ROLAND PMO monitored contractor performance independent of international considerations. Use was made of technical support within the HAWK PMO office, the MICOM RDEC, and when warranted, independent expert technical consultants.
6. Direct Technical Contribution	There was little opportunity for direct technical contribution by U.S. ROLAND TMO personnel due to the nature of the program. However, as with TMO for all U.S. programs, the focus and concern needs to be for the system to satisfy the User's needs. Two U.S. ROLAND activities can be called direct technical contributions: The safe and effective integration of the Honest John trucks into ROLAND. The upgrade of the ROLAND radar to simplify operations and to minimize calibration.
7. Control of and Access to Technical Data	Control of and Access to Technical Data was not an issue for ROLAND. Transfer of the technical data package from the European developers was arranged by Hughes Corporation and Boeing Corporation.
8. User Participation	User participation for the U.S. ROLAND production was limited to test. The interests of the user were of paramount concern for U.S. ROLAND TMO, and resulted in a truck improvement and a radar improvement.
9. Cost Share and Work Share	Cost Share and Work Share did not directly apply to the U.S. ROLAND program and had no bearing on TMO.

Table 9: ROLAND TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
10. Preparation of Contract SOWs	Preparation of Contract Statements of Work (SOW) was a critical activity for U.S. ROLAND TMO, however, due to the existing technical data package, the SOWs primarily addressed production. There were no international considerations for development of these statements of work.

b. TMO Program Feedback Considerations

Table 10 captures the TMO Program Feedback elements for ROLAND.

Table 10: ROLAND TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	International Executive Control did not apply to the U.S. ROLAND program.
2. TMO Funding	TMO Funding was provided by the U.S. and there were no direct international considerations. ROLAND development was essentially complete prior to the U.S. becoming involved and did reduce cost risk, although, there was an effort to either eliminate the program or to reduce the cost of the U.S. ROLAND program by one half. The ROLAND international agreements may have motivated congress to insist that funding be maintained.
3. National Interaction	Following program initiation, there was no significant national interaction between U.S. Government personnel and European personnel. The burden for international coordination fell on Hughes and Boeing personnel, at the technical level and with European contractor counterparts. Liaison was maintained with the European ROLAND program office by the U.S. ROLAND program office, however, this had no significant impact on TMO.
4. US Acquisition Review prior to next phase	U.S. Acquisition Review Prior to the Next Program Phase. The U.S. ROLAND Program went directly to production and there was no follow-on acquisition phase and thus no acquisition review prior to the next program phase.

3. Elaboration

a. Discussion: ROLAND International Organization

The U.S. ROLAND program was a production program that was based on a European system, ROLAND III. ROLAND III was developed by a consortium of European countries. Compared to the HAWK program, ROLAND was a reverse situation. At the time the U.S. became involved, the European ROLAND office included six European countries headed by a French general who dressed in Civilian Clothes.

ROLAND was supplied by the 6 nation European consortium and the U.S. hired Boeing and Hughes. They had to make the arrangements for the data package to come to them. The reason for U.S. involvement in ROLAND was cooperation in international sales. They developed it and we produced it over here. In the case of HAWK, it was developed over here and produced over there. For ROLAND, we didn't buy systems from them, we just took the ROLAND data package, cobbled it up and made something (21 June 2001 Interview with John Robins.)

The European consortium had their office in Paris, and we had a Liaison officer. The work environment was different from the work environment we are accustomed to in the U.S.

Never get there before 10:00 a.m. ... you would always leave by 2:00 p.m. Never call anyone at home, always leave before Friday at noon, always very formal. French people are very different. ... I also had to admire the people in the office. Many of them spoke fluently 6 languages. They put us to shame. They never argued. They always listened. They would take in and they would negotiate. They were shrewd negotiators. (June 21 2001 Interview with John Robins).

b. ROLAND Example: Management of Requirements

I guess the best I ever felt. ... I was one of the early civilian product managers. I was called at 10:00 pm and was told that I needed to see the vice chief of staff of the army in Washington and tell him why my program cost so much. And so I went out the next morning, opened my safe and got some stuff out, got on the Redstone Rocket and flew into Washington and got in a taxi and went into the Pentagon.

I'll tell you, those people, ... when the vice chief wants to see you, you go through layers real fast. They were pushing me into his office and set me down in the hot seat. There were all the generals and friends, I thought they were my friends, and they set me down in the hot seat in front of the Vice Chief of Staff. He looked at me, and I said, you asked me to come and I'm here. The problem was that we were going to deploy ROLAND with the New Mexico National Guard. The intention was for the National Guard to deploy anywhere in the world within 24 hours and protect airfields and so forth. Looking at it, it was real clear what it was going to take to keep the system certified and viable. ... He said, 'Cut your program cost in half and you've got a program.' And I just said, ... 'Sir, if it is cut, the Army can't afford this program. I'm your manager, and I'll be glad to cancel it for you.' People were crawling under tables, and, you don't talk to the vice chief of Army that way. I said, 'Sir we don't want to give the troops junk.' I said, 'I have looked at this program and I know how important it is to keep costs down. But I also know that if I can't put these, ... you've got these 20 year old honest john trucks you got em mounted on, and if I can't put jake brakes on these trucks and etc to keep them safe, because I've seen the trucks come off the hills in Korea with HAWK loads on them. The ROLAND load is bigger than HAWK loads, ... then we're going to lose troops.' I said, 'We've got to maintain the system so that it works.' Also, I said, 'We found out that if you don't train the troops, ...' we had a trainer just for training then we had a mini trainer that was out, then we found out on a curve how many days they could stay out without losing their skill, it was 90 days, and you could just see it, it was like driving too long. I said, its true, we just can't deploy this system if you can't support it. And I'm not trying to say, ..., I'm your manager. If the money is there, I'll be glad to deploy it. If it's not, you tell me and I'll terminate it. I'm the manager to run what you want. I'm not just to put it out there, and I'll do that if the money is there. But if the money doesn't fit, I'm the manager to terminate it.' Oh, I'll tell you, ... I went home, and I got all the people together, that were working so hard, ..., we were just before deploying it, and I called civilian personnel and I told them, 'I don't know what is going to happen.' The funny thing was that the vice chief then went over to the senate and said, 'I have cut these things down, including ROLAND.' And all I had said to my people in Washington was 'you send me a message to tell me to terminate and I'll terminate.' Well

he went over to the senate and said he wanted to terminate, ok and the chairman of the Armed Services Committee said, 'We like your suggestions except for one, and that is that we don't want you to termination ROLAND.' Now ROLAND is just a little pea in all that stuff up there. ... And so they couldn't send me a message to terminate, and we were held in this little purgatory here. And so finally it got to the point where the contractor said we'll keep working without any money. ... and I said, no you won't. And so I sent a message back, Barring the fact that I don't have the money to continue and it's against law so and so to let the contractor train troops, support, etc, I plan to terminate on such and such a day if we don't receive the money.' Well, about 48 hours before the end of the time period, the money came. We deployed ROLAND (June 21, 2001 Interview with John Robins).

c. ROLAND Example: Management of Technical Risk

One of the risks had to do with the reliability and calibration of the radar. This risk was uncovered during user testing:

They were ready, ... they had been producing for a year when I was sent to ROLAND. I went in and they were about to start the engineering user test. Production had been going for a year and they hadn't even done the test yet. I said I guess we better start. We had a Captain at White Sands. They had all these spare parts, and he said how good it was and what good results they'd been having. And so, I had to get a test manager for ROLAND. He was someone I knew and trusted, and he was someone I knew I could work with. I saw that was what was going to do it. Then he [my test manager] said, everything's looking so good, what your going to do is have a system test. Take the hardware, the spare parts and you've got the manuals. I told the Captain, operate from the test plan, and I want you to use the manual. If have to depart from the manual, don't do it and then tell me, just write it down and say, this doesn't work. If it's not in the manual, these troops won't have someone around to help them. Well it turned out, they went out and the next thing they couldn't do anything. They couldn't hit anything and couldn't even fire. And the contractor was saying, 'But we did it, and hey, you won't let us do this!' We did a root cause analysis to find out what

was going on. It turns out the contractor had been doing tests on their own to let us know how good the system was. They were out there calibrating the radar with the \$1.5M spare part, and they were calibrating that radar with an elaborate machine while the drone was in the air. Then they would move from the calibration to the drone and shoot down the drone. Well, the operating procedures said you only do this calibration once every three months. This captain dutifully had followed procedures, and they said, 'No you've got to calibrate it.' The captain said, 'No, you only do it once every three months.' It turned out the thing went out of calibration and wouldn't shoot a thing! They had to go in and make a major change so that it wouldn't go out of calibration. But it wouldn't have been any good to the troops otherwise.

It comes back to a simple thing that is true whether the program is international or not. You are trying to certify to the troops that the system will work the way that it is advertised. That is the first time that Hughes had been through one of MICOMs root cause analysis. They learned a lot.

International is more complex Their test ranges are set much like ours but they use different equipment. Many times there are quirks in the test range that you don't find until you start testing, that will invalidate the test. These are things the TMO needs to be sensitive to. Many times it is the Italian or French ombudsman on the team that will have to go back and tell their folks that they are messing up. [And this is potentially embarrassing to the country, and so communications becomes important] (21 June 2001 Interview with John Robins).

C. LANCE

Information about the Lance program has been primarily obtained from an interview with Mr. John Robins who was the civilian Manager for Lance. While Lance did not involve significant international participation during development, the TMO lessons learned have merit.

1. Overview

Figure 15 depicts the LANCE missile and launcher. LANCE was a mobile field artillery tactical missile system used to provide both nuclear



Figure 15: LANCE MISSILE (from <http://www.redstone.army.mil/lance/summary.html>)

and non-nuclear fire-support to the Army. It was designed to attack key enemy targets beyond the range of cannon artillery. It was a highly mobile, medium-range, fin stabilized, all weather, surface-to-surface missile weapon system. LANCE's primary mission targets were enemy missile firing positions, airfields, transportation centers, command and logistic installations, critical terrain features (defiles, bridgeheads, main supply routes, etc.), and large troop concentrations.

The missile was incrementally guided using the Directional Control Automatic Meteorological (DCAM) compensation concept. The LANCE

missile was launched by a high thrust booster that propelled it out to 1500 meters. The boost phase direction was controlled by a gyro commanding secondary injection into the booster. The booster cut off and the variable thrust sustainer, controlled by an accelerometer, provided the exact amount of thrust to equal the missile drag. The result was a predictable trajectory that essentially eliminated errors caused by atmospheric disturbances or changes. The missile was aimed using field artillery techniques plus the variable booster time. Unlike other Army missiles that use solid propellants, the LANCE used a prepackaged, liquid fuel that eliminated any need for fueling in the field and gave LANCE a short reaction time. It was capable of delivering nuclear warheads to a range of 75 miles and conventional warheads to a range of 45 miles.

LANCE was actively deployed until the early 1990s. In 1991, President George Bush announced a unilateral cut in nuclear weapons, which was followed on 5 October by a similar announcement by President Mikhail Gorbachev of the U.S.S.R. Although the Soviet Union collapsed shortly thereafter, the United States later reaffirmed this nuclear arms reduction agreement by signing a treaty with Russia, Belarus, Kazakhstan, and Ukraine on 23 May 1992. The final LANCE battalion stood down at Fort Sill, Oklahoma, on 30 June 1992. After being demilitarized, excess LANCE missiles were set aside for use as targets (<http://www.redstone.army.mil/history/lance/summary.html>).

2. Application of the TMO Framework

a. TMO Considerations

Table 11 captures the TMO considerations elements for LANCE.

Table 11: LANCE TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	LANCE was developed independently by the U.S. and control of the program remained within the U.S. for the life of the system. The International community became involved through foreign military sales to NATO countries and Israel.
2. RDEC/ Contractor Technical Support	Research Development and Engineering Center (RDEC)/Contractor Technical Support. Technical support from RDEC and other sources played a crucial role in the development of Lance, although international considerations for technical support were minimal. A key-concept that made Lance possible in an era of unreliable and inaccurate electronics was the variable thrust sustainer, conceived by Dr. McCorkle and Bob Canard at RDEC. Effective exchange of information, including this key concept, between the Lance TMO effort and the prime contractor was important to the success of the program.
3. Management of Technical Requirements	Management of Technical Requirements did not involve the international community. Lance was developed independently by the U.S. Army, and the configurations of upgrades were managed by the U.S. Army.
4. Management of Technical Risk	Management of Technical Risk involved teamwork between Government TMO and contractor developers. Creation of detailed plans, using PERT tools, may have helped to identify problem areas early, but also created additional risks. There were no technical risks directly associated with the international aspects of the program since the international involvement began following the completion of the development activity.
5. Technical Monitoring Capability	Technical Monitoring Capability was initially centered on a massively complex PERT based schedule and resource tracking system. However, when it became apparent that the PERT based approach was not being effective, the approach was simplified to focus detailed planning on near term events. Quantified milestones were instituted to provide intermediate goals that had to be met in order to continue development beyond clearly defined technical goals. However, there were no international considerations for technical monitoring.
6. Direct Technical Contribution	Direct Technical Contribution from TMO was crucial to LANCE. Concepts developed by RDEC, such as the variable thrust sustainer made LANCE more accurate and reliable than would have been possible otherwise.
7. Control of and Access to Technical Data	Control of and Access to Technical Data was not an issue for LANCE because no foreign participation occurred during development.
8. User Participation	User Participation was minimal during LANCE development.

Table 11: LANCE TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
9. Cost Share and Work Share	Cost Share and Work Share were not an issue for LANCE development. During production, costs for purchase of LANCE by other nations were borne by the purchasing nation.
10. Preparation of Contract SOWs	Preparation of Contract Statements of Work (SOW). There were no international considerations associated with preparation of the LANCE SOWs.

b. TMO Program Feedback Considerations

Table 12 has the TMO Program Feedback elements for LANCE.

Table 12: LANCE TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	International Executive Control was not applicable for LANCE.
2. TMO Funding	TMO Funding did not include any unique international aspects.
3. National Interaction	National Interaction was not an issue for development of LANCE.
4. US Acquisition Review prior to next phase	There were no unique international aspects of acquisition review for LANCE.

D. MEDIUM EXTENDED AIR DEFENSE SYSTEM (MEADS)

Information for this MEADS TMO discussion has been taken primarily from an interview with Mr. William Bishop, 22 July 2001, and from the personal experiences of the author. Mr. Bishop is the Chief Engineer of the International Program Office (IPO) for MEADS, directing a technical staff of engineers from Italy, Germany and the United States.

Mr. Bishop has also provided invaluable advice and guidance to the author in the development of this thesis. The author is on technical staff to the U.S. MEADS National Product Office (NPO).

1. Overview

An overview of the planned MEADS system is shown by Figure 16.

MEADS SYSTEM CONCEPT (MSC)



M502t

Figure 16: MEADS System Concept (from US MEADS NPO Program Documentation)

MEADS began life in August 1990 in the U.S. with the approval of the Corps Air Defense Capability Mission Need Statement (MNS). The Army was given ORD responsibility, and the system was given the name CORPS SAM. The Milestone 0 Acquisition Decision Memorandum (ADM) approved entry into the Concept Exploration acquisition phase and required the project office to explore cooperative opportunities with allied

countries. Countries contacted for potential involvement included Australia, Canada, France, Germany, Israel, Italy, Japan, Korea, The Netherlands, Norway and United Kingdom. In the 1994 time frame, detailed discussions began with Germany and France. In 1995, Italy joined the discussions and a formal Statement Of Intent (SOI) was signed. An interim management office was established to coordinate program activities prior to establishment of the NATO MEADS Management Agency (NAMEADSMA).

Development of a MEADS Memorandum of Understanding (MOU) was begun in 1996. France withdrew prior to MOU signing. The Program Definition/Validation (PD/V) phase was initiated to competitively select the best technical approach and to select the MEADS prime contractor. MEADS International Consortium including Lockheed-Martin, won the competition.

The down-select to MEADS International was completed in December of 1999. Shortly after the down-select was complete, funding concerns within the U.S. led to reconsideration of U.S. commitment to the program. An Analysis of Alternatives (AOA) had been done by the U.S. Army Air Defense School (USAADASCH) during the PD/V phase along with a Cost As and Independent Variable (CAIV) analysis by the U.S. National Product Office (NPO). The U.S. agreed to continue the program contingent on use of the PAC-3 missile in lieu of developing a new MEADS missile. Additionally, full program funding was not committed by the U.S. and an interim three year Risk Reduction Effort (RRE) was established. RRE was supposed to reduce risk and provide an opportunity to better understand program cost. The U.S. then established full funding for MEADS in the Future Years Defense Plan.

The change in the program led to a re-evaluation of program commitment by the German and Italian partners. Complicating matters, the German Government changed and a re-evaluation of German defense

priorities began. However, these difficulties have been overcome, and the 30 Month RRE contract was awarded with MEADS International in July of 2001.

2. Application of the TMO Framework

a. TMO Considerations

Table 13 captures the TMO Consideration elements for MEADS.

Table 13: MEADS TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	Italy, Germany and the United States are partners in the MEADS program. Current and planned Memorandum Of Understandings (MOUs) establish the MEADS program as an international co-development program, where the three nations establish operational requirements, select the prime contractor, develop the system, and produce the system.
2. RDEC/ Contractor Technical Support	Access by the IPO to Research Development and Engineering Center (RDEC)/Contractor Technical Support for MEADS TMO is proving to be difficult. Some access is provided through U.S. NPO that is not subject to Cost Share/Work Share. The IPO does have access to Contractor Technical Support that is subject to cost share and work share.
3. Management of Technical Requirements	User requirements have been clarified and updated, particularly related to system interoperability with other Joint system. Obtaining international agreement for clarifications and updates of the International Technical Requirements Document (ITRD) may prove difficult.
4. Management of Technical Risk	Technical Risk Management is made more difficult for MEADS because of technology transfer restrictions. The United States Army would like to include its most advanced (and sensitive) missile and sensor technology in the MEADS system. However, the U.S. plan to time phase the foreign release of sensitive technology critical to the MEADS program complicates risk management. The IPO is not able to address this risk early in the program, and will not be able to address this risk until the technology is released. This is a dilemma for all parties and is an area where the U.S. MEADS NPO can help to address technical risk. Some strain is put on the international partnership when partial access to MEADS critical technology is provided by any of the partners. This has caused some frustration.

Table 13: MEADS TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
5. Technical Monitoring Capability	Technical Monitoring Capability for the MEADS program will be performed by NAMEADSMA's TMO activity. While the details have not yet been worked out, performance metrics will be developed to measure key performance parameters. Software metrics will be used to help understand software development status and an earned value management system will be used to understand expended resources for planned activities.
6. Direct Technical Contribution	f. At appropriate times it is crucial to clarify existing requirements and in some cases it may be necessary to add, modify or delete requirements. Development of contract Statement Of Work for future contracts is important. Activities that will directly impact MEADS TMO include trade studies, contract technical deliverables, electronic data access, scheduled reviews, simulations, quality assurance, configuration management, training, logistics, test requirements, subcontractor flow-down, and coordination with external programs.
7. Control of and Access to Technical Data	Configuration Management (CM) and Government approvals to use information are difficult areas for MEADS. For CM, delays in approving changes to requirements and specifications can be expected due to the international nature of the program. Related to Government approval for use of sensitive information, a specific time phased release plan has been developed to govern the timing of the release of specific information, such as PAC-3 missile information. The U.S. does not wish to release information before it is needed in the program, particularly because the partner nations (including the U.S.) have not yet committed to participate in the full up development program.
8. User Participation	User Participation is different for European development programs than for typical U.S. Army development programs. In U.S. Army programs, user participation is encouraged early and throughout development for feedback on technical aspects that will affect the User. However, in Europe the same is not done. This difference in approach will be addressed as the MEADS program continues.
9. Cost Share and Work Share	The twin issues of MEADS Cost Share and Work Share have a large impact on TMO for MEADS. It is tempting to leave these issues to others to deal with, but the issues affect TMO at every level. This affects prime contractor work allocation, it can affect technical support contractor personnel selection, it affects the organization of the NAMEADSMA office and if affects the ability of NAMEADSMA to obtain expert technical support on short notice when problems need to be solved.

Table 13: MEADS TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
10. Preparation of Contract SOWs	Preparation of MEADS Contract Statements of Work (SOW) are more complex for the MEADS program than for a typical U.S. MDAP. For a U.S. MDAP, the PM typically is given minimal external oversight in structuring contract SOWs. However, in MEADS, the three partner nations have taken a strong interest in ensuring the contract SOWs with the prime contractor satisfy national interests. This makes preparation of SOW time consuming and requires extra up-front planning.

b. TMO Program Feedback Considerations

Table 14 captures the TMO Program Feedback elements for MEADS.

Table 14: MEADS TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	Executive control for MEADS is more difficult than executive control for a U.S. only MDAP because there are more customers. The more participants there are in any activity, the harder it is to please everybody. For MEADS, the TMO issues that involve difficult executive action are system requirements, prime contractor work requirements, and balanced work share.
2. TMO Funding	b. An important issue with MEADS TMO Funding relates to balancing work share to match MOU agreements. Some limited funding is available within the NPOs that is not subject to work share considerations, however, use of this funding is at the discretion of each NPO. Although operating outside the IPO, some useful contribution has been made as a result of independent NPO funding, and it is hoped that future collaborative effort is possible.
3. National Interaction	c. National Interaction between NAMEADSMA and the partner nations is both enjoyable and frustrating. It is enjoyable because participants can meet and get to know interesting people from other countries who have a common purpose. The frustrating part involves restrictions on communications and technical exchanges resulting from the MEADS MOU and national regulations.

Table 14: MEADS TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
4. US Acquisition Review prior to next phase	d. U.S. Acquisition Review Prior to the Next Program Phase is critical for the eventual success of the MEADS program. Navigating the waters of the National acquisition processes is difficult for NAMEADSMA because direct access to the National decision making processes is not available to NAMEADSMA. Complicating things even more regarding the U.S. acquisition process, acquisition personnel in the U.S. are not accustomed to international acquisition.

3. Elaboration

a. Discussion: MEADS Program International Organization

Figure 17 highlights key aspects of the current MEADS organization. The North Atlantic Treaty Organization (NATO) MEADS Management Agency (NAMEADSMA), establishes and executes contracts with the MEADS Prime Contractor, MEADS International. The U.S. MEADS NPO supports the U.S Steering Committee member, and provides an interface to NAMEADSMA to the U.S. acquisition infrastructure. The MEADS Executive Subcommittee (MESc) is an international coordinating body that supports the Steering Committee, whose membership includes the Product Managers from each nation's NPO.

It may appear to the U.S. acquisition community as if the U.S. MEADS NPO is responsible for the program. It is not. As shown figure 17, a U.S. MEADS National Product Office (NPO), separate from NAMEADSMA, supports the U.S. Steering Committee member and provides NAMEADSMA a primary point of contact for interacting with the U.S. acquisition community. The U.S. MEADS NPO interacts with the

MEADS MANAGEMENT STRUCTURE

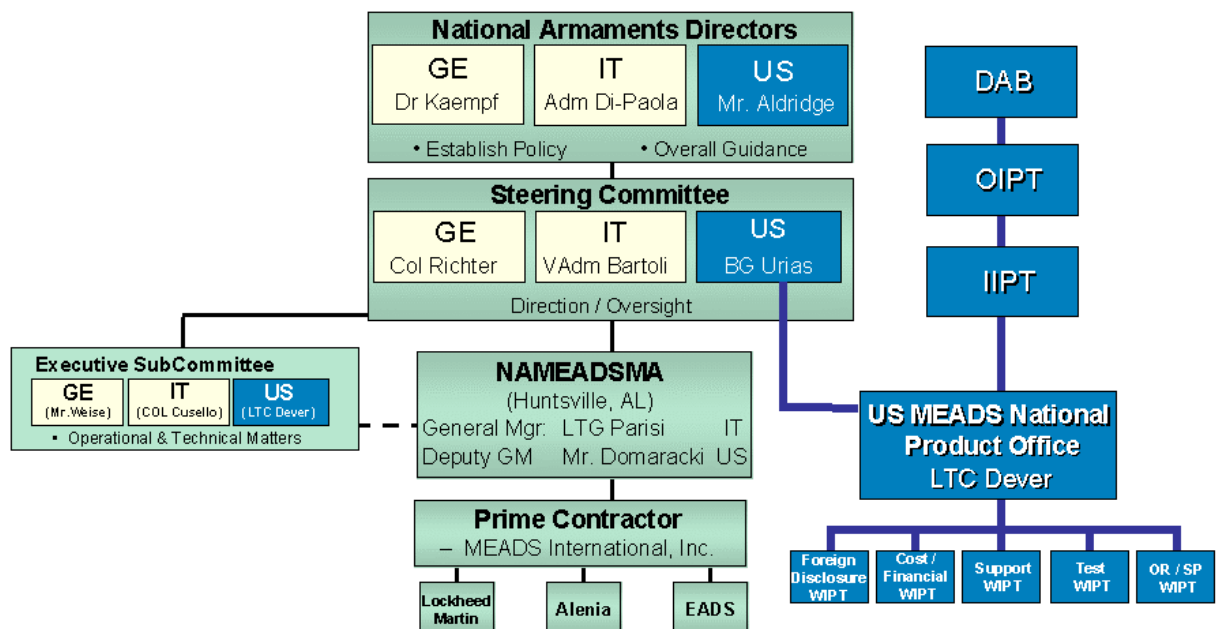


Figure 17: MEADS Management Structure (from US MEADS NPO Program Documentation)

U.S. Defense Acquisition Executive, Overarching Integrated Process Team (OIPT), Integrating Integrated Process Team (IIPT) and Working Integrated Process Teams (WIPTs). The NPO plays another role because of the U.S. desire to limit foreign access to technology. The U.S. MEADS NPO facilitates technology transfer, while ensuring proper foreign release approve is obtained prior to transfer. The U.S. MEADS NPO also does some technical work to understand and mitigate technical risk.

(1) MEADS TMO Organizational Aspects and NAMEADSMA. The NAMEADSMA engineering division is responsible for MEADS TMO. TMO is more complex for NAMEADSMA than for a U.S. only program. This is due to difficulties in changing organization structure to match technical needs and to match the abilities of the

engineering staff. The basic NAMEADSMA organization structure was established by the MOU, roughly according to work sharing agreements, and changes to that structure must be approved by the Steering Committee. However, the Nations feel they own the positions that have been allocated, and this makes it difficult to move people within the organization as needs change. Fortunately, each nation has brought talented people into the program and this helps to offset the problem.

The nations tend to look at those positions as if they own those positions, therefore they have a say in what those positions do. That is not unique to MEADS. They have the same sort of thing in Europe where they do international programs. This is just one of those things that with an international program you get involved in. The nations tend to design the organization, somewhat, and to a large extent, organize it based on work-share and primarily on the tasks that need to be done. Now they don't ignore work to be done, but work share considerations are additional constraints on the organization. (Interview with William Bishop, 22 July 2001).

(2) MEADS TMO Organizational Aspects, the Steering Committee and the MESC. The Steering Committee oversees the activities of NAMEADSMA and the MESC, consisting of the head of the NPOs from each nation supports the Steering Committee. The Steering committee does not get involved in the day to day technical decisions that affect NAMEADSMA TMO. Some technical issues related requirements and technical Statements of Work (SOWs) get special steering committee attention, beyond the executive attention that would occur for a U.S. only program. For a U.S. only program, oversight can be expected for requirements, through the Operational Requirements Document. However, a U.S. Program Manager (PM) will normally own the SOW and system specification. NAMEADSMA must obtain approval of the Steering Committee for substantive changes to the contract technical specification and the SOW. This affects TMO because the

process for establishing the basis for and any changes to the work to be performed are tedious and time consuming.

(3) MEADS TMO Organizational Aspects and the U.S. MEADS NPO. As with all U.S. personnel external to NAMEADSMA, the technical-staff within the U.S. MEADS NPO have difficulty with the reality that the U.S. is not in control of the MEADS program. This confusion may exist because of limited international-program experience, the need to exchange technical information with other U.S. programs, and the desire by individuals to make meaningful technical contributions. As with any group it takes some time to sort out and fully understand roles and responsibilities. While working technical transfer issues and coordinating with other programs, opportunities are occurring for U.S. MEADS NPO technical personnel to contribute expertise. Coordination between NAMEADSMA and the U.S. MEADS NPO has begun to occur to focus U.S. MEADS NPO technical resources on the technical issues that need to be worked. To the extent that U.S. personnel are seen as supporting NAMEADSMA, this will be successful (Author's opinion).

b. Discussion: RDEC/Contractor Technical Support

There is recognition by NAMEADSMA and all of the national participants of the potential high value of RDEC technical support, but no mechanism has been established to enable control and tracking of technical support work share when RDEC is involved. To partially overcome this difficulty, a System Engineering Technical Assistance (SETA) corporation, MEADS Limited Liability Corporation (LLC), has created to provide NAMEADSMA access to technical support. MEADS LLC will help to fill the technical support needs of the MEADS program, but there remains a desire to enable access to RDEC because of proven

expertise with simulations, software and radar technology. Some support from RDEC is planned through the U.S. MEADS NPO, however, this support is not subject to cost sharing and is difficult to justify. Within the U.S. it is felt that the costs for technical support should be shared by all the partners because all partners benefit. However, some technical aspects of MEADS are uniquely U.S., German or Italian, such as interface to national command and control systems, and applying independent funding to solve technical problems unique to the U.S. use of MEADS may be justified. U.S. funded technical support for interfacing with U.S. provided subsystems such as PAC-3 may be justified because time phased access to PAC-3 information is being provided. Ultimately, support from RDEC to the MEADS program may have to be funded independent of cost share agreements, however, a method of satisfying the MOU cost share agreement would be preferable, at least from the U.S. perspective.

An example of the U.S. MEADS NPO providing technical support with direct impact on MEADS TMO involves frequency allocation support. It is in the interest of the three MEADS partner nations to ensure the frequencies to be used by MEADS radars are acceptable for the areas in the world where MEADS is expected to be deployed. Ensuring this involves analysis of internationally agreed upon frequency allocation tables. While on the surface this appears straight forward, it is not. Demand for spectrum has exploded during the last decade, and it is becoming difficult to ensure radars will have the spectrum available for operations. In any case, the U.S. MEADS NPO is dedicating effort to address this problem until the issue is resolved. This effort is independent of cost share and work share considerations. Italy and Germany are supporting similar efforts. NAMEADSMA is playing a coordinating role, but is not funding the support.

c. Discussion: Management of Technical Requirements

Management of technical requirements in any complex system development is difficult. On the one hand, requirements stability is desired in order to minimize change and resulting cost. On the other hand, if the requirement is wrong and a change will be needed later anyway, then conventional wisdom is that the earlier the error is corrected, the lower the cost will be. In the International Considerations section of this thesis, (Section C, Chapter II) the common desire of international programs to avoid requirements change was highlighted. MEADS is no different. Within the TMO staff of MEADS there is a growing awareness that the International Requirements Document needs clarification in many areas. However, there is strong reluctance to add, delete or change the intent of any requirement. The ITRD will establish the technical requirements for the MEADS contract when the formal development program begins.

From the perspective of requirements stability it is good not to change the ITRD. From the perspective of the U.S. User, however, change is necessary to align the ITRD the U.S. MEADS Operational Requirements Document, which has changed in some of its technical detail. During the world-wide staffing approval-process of the U.S. MEADS ORD, detail has been added that makes the ORD inconsistent with the ITRD. Fortunately, much of the change to the ITRD that is desired by the U.S. can be looked at as a clarification of an existing ITRD requirement. Also fortunately, the US ORD remains almost entirely consistent with the International Common Operating Requirements (ICOR) document, which is intended to serve the function of the ORD for the MEADS program.

The U.S. MEADS NPO has expended considerable resources over the course of a year to understand the differences that have emerged between the ORD and the ITRD, and to suggest clarification

language for the ITRD. NAMEADSMA has also expended considerable resources in trying to understand the nature of the suggested clarifications. The need has been recognized by both organizations to collaborate at least to understand the issues. It remains to be seen what, if any clarifications or changes are made as a result of this requirements review process. This experience highlights the difficulty of managing requirements change for an international program, even prior to start of formal development.

d. Discussion: Configuration Control

Configuration Control of technical data is critical for any program. The uniqueness for MEADS, is that getting three nations to agree upon a particular change is difficult. An effective mechanism for timely approval of engineering changes during the future development effort has not been established.

It is usually difficult to obtain Steering Committee agreement on complex technical issues in a timely manner. From that standpoint, I don't yet know how we are going to do configuration management downstream during the D&D program phase. The Steering Committee is presently the only body that can approve an engineering change to the technical requirements. I've been on development programs where you have had to process performance requirements changes within a matter of a few days. You found something out, you've got to make a change. Unless the General Manager is appointed chairman of a CM board, it will take us a long time to obtain agreements for change. Then we will have a lengthy delay, diminishing our ability to respond to dynamic situations in a timely manner. (William Bishop Interview, 22 July 2001).

e. Discussion and Example: User Participation

For MEADS Germans and Italians have difficulty with the idea of getting their User involved once the initial requirements have been established.

This is a unique thing that we've run into, and it's one of those things that I just have to file as incredible. There is a mindset in the US that during the acquisition process when you're building advanced systems you want user involvement, practically from day one. And you want user involvement practically through the entire program. You even have a TRADOC system manager who is at roughly the same level as the program manager in the acquisition chain. But Europeans don't necessarily do that. And, some of them have a difficult time in wanting to bring their user people into the process at all. That is something that has astounded me. And I don't know the background of why that is, but in Germany and Italy's process, I've learned to accept their reluctance for direct user involvement in the acquisition process. To them it probably makes perfect sense. They have established their procedures for getting user input into requirements and there is very little if any (that I can discern) direct user input into project offices in Germany or Italy. So, when you see the need for user input and you have to go to the three nations to request User participation, then the US has a tough time getting that view across. And that problem has to be solved, in my opinion, for all three nations, because we are ultimately building something for the user. You just don't want to go for 8 years and suddenly drop something on the user. (William Bishop Interview, 22 July 2001).

An example of the difference between U.S. user participation and European User participation involves operational testing. In the U.S., a system operational test involving Users in an operational configuration is mandated by law prior to fielding of the system. There is no relief given to international programs. There is no similar requirement in Europe. To some extent this might be solved by how the developmental test program is structured for MEADS. It may be possible to obtain agreement for a partial operational test of the system that demonstrates core functionality that is common for all three nations. However, this may take a change in thinking on the part of all three nations. Otherwise we may end up effectively with three operational tests, and that will not be cost effective.

f. Cost Share and Work Share Importance to TMO

Cost Share and Work Share, ... that is a super, super, super, biggy for TMO. You almost want to say, 'well that is politics.' But you can't do that. You would like to focus on just the Engineering. But the engineering affects work-share! I've spent too many hours talking work-share. But, this a big, big thing in a international program, particularly to the Europeans. It ought to be to the US too, but I think the Europeans have more experience with international programs, and they understand cost-share and work-share because they have had to. And that has to be balanced, just like a lot of other things on the program. And that is at the Steering Committee level, and they have to work through that, but it is a really big impact and this is another characteristic that makes TM unique on international program.

How can that affect you? Well, things that you want to do in terms of putting people on a particular problem. If its outside of a support contract and you feel you need special expertise somewhere, then that becomes an item for cost share/work share. It ought not to be that way, but it is. If I have an unexpected fire going on at my house and I have to call the fire department, then that work will get involved in a cost share/work share issue that we'll have to resolve later on, somehow. That's just a fact of life. That affects TM fairly substantially. [William Bishop Interview, 22 July 2001).

g. Discussion: Statement of Work

The tri-nation involvement in SOW preparation has led to increased time to coordinate with staff from the three NPOs to prepare contract SOWs.

Cost share/work share issues flow into Contract SOW preparation. Not only is it that you have to worry about what it is you have got to do to accomplish the work, but also that SOW will be looked at by the nations, in terms of 'what is in it for our industry.' The prime contractor, when he proposes, has to look at the SOW and the cost share/work share constraints that he has and he has to balance the best

he can. That is not easily done, but he has to figure out how to do it. ... You mentioned earlier about the nations reviewing the SOW, ... that was a horrendous exercise, and you just have to face the fact that SOWs are going to take a long time to coordinate. And we have to figure out a better way to do it. I don't think we did the last process very well. We are going to have to do a better job for the Design and Development (D&D) phase. But that is something the nations are going to get involved in, and meticulously pick over words and paragraphs, and that's just the nature of the beast, it comes with the territory. But that is a unique thing about international programs. A draft D&D SOW exists, but there are other things that have impacted it. What we don't want to do is go in and open up things that have already been settled. But there have already been impacts to that D&D program. That SOW will not be a simple thing to coordinate. I don't know any other way to do it than to get started on it early, because it is probably going to be harder and take longer than anticipated (William Bishop Interview, 22 July 2001).

h. Discussion. National Interaction

For MEADS, national acquisition process interaction is either formally through the Steering Committee or informally through other means. In the case of interaction with the U.S., most informal interaction is through the U.S. MEADS NPO. This is to done to help ensure that the U.S. speaks with one voice when interacting with NAMEADSMA and to help ensure that sensitive U.S. information provided to NAMEADSMA is authorized for use in the MEADS program. Often U.S. personnel working for NAMEADSMA feel cut off and as if they are being treated as second class citizens because they are sometimes treated as foreign nationals (For security purposes, NAMEADSMA is considered a foreign agency). However, part of the issue here is the discomfort felt by Italian and German NAMEADSMA personnel when U.S. NAMEADSMA personnel participate in U.S. only activities. Both viewpoints are understandable and difficult to address. The result is

that often the U.S. personnel at NAMEADSMA are not able to participate in U.S. acquisition meetings or technical meetings that may have a direct bearing on the program. This uncomfortable situation is being handled on a case by case basis by management and individuals.

i. Discussion. U.S. Acquisition Review Prior to the Next Program Phase

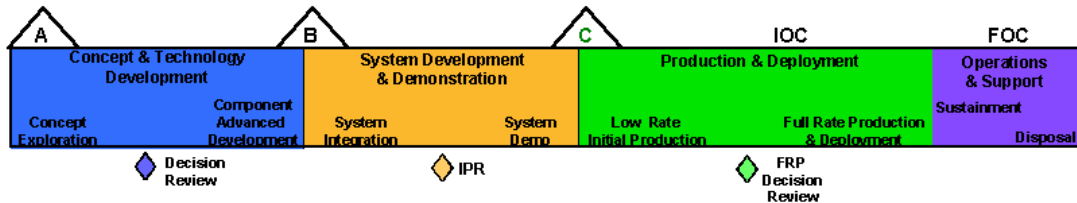
U.S. Acquisition Review Prior to the Next Program Phase is critical for the success of MEADS. Navigating the waters of the National acquisition processes is difficult for NAMEADSMA because direct access to the National decision making processes is not available to NAMEADSMA. Complicating things regarding the U.S. acquisition process, U.S. acquisition personnel are not accustomed to international acquisition. U.S. statutes and regulations, developed during the Cold War, and evolving over time have not yet caught up with international MDAP acquisition, although much progress has been made. Ideally, one process would exist for the U.S., Germany and Italy to decide upon continuation of the program at the end of each program phase. However, there are three separate processes, each with its own data requirements and institutional decision criteria.

The U.S. MEADS NPO plays a critical role in the U.S. acquisition process to transfer data from the MEADS program to the U.S. decision makers to enable continuation past the current Risk Reduction Effort and into the MEADS D&D phase (roughly equivalent to the DOD 5000 System Development and Demonstration phase, see Figure 18).

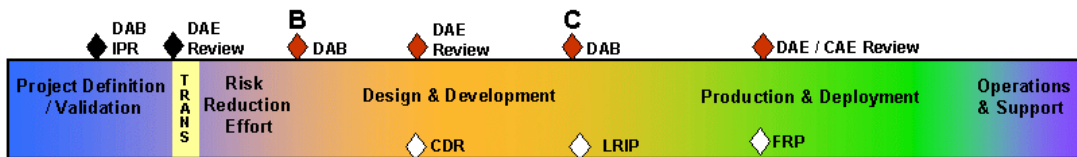
This is an uncomfortable role for the U.S. MEADS NPO because the NPO is accountable to the U.S. acquisition process for program performance but has no responsibility for program execution. The January 2001 updates to DODD 5000.1 and DODI 5000.2, along with the June 2001 update to the Mandatory MDAP procedures in

ACQUISITION PROCESS

The Current DoD 5000 Acquisition Model



MEADS Current Program



The International Program Phases Coincide With DoD 5000 Series
With Program Initiation (MS B) Occurring Prior to D&D

Figure 18: MEADS Acquisition Compared with DOD 5000 (from US MEADS NPO Program Documentation)

DOD 5000.2-R include special considerations for international programs, however, the U.S. MEADS NPO is severely challenged to address the expectations of the U.S. acquisition process. The basic difficulty is that acquisition documentation normally developed by an MDAP PM are not being developed by NAMEADSMA. Yet the U.S. acquisition community expects these documents. To obtain the documents desired, the U.S. MEADS NPO may have to independently develop the documents.

However, this is not the desired solution. It would be better for the U.S. to rely on a common set of acquisition documents developed by NAMEADSMA that will satisfy all of the partner nations. To make this possible, relief may be needed from DOD 5000.2-R, June 2001 that states in paragraph C7.11.3.3 the following: “C7.11.3.3 The DoD Component shall remain responsible for preparation and approval of

DoD-required documentation and reports (specifically: ORD, C4ISP, TEMP, APB, Delegation of Disclosure Authority Letter, etc.).”

In some cases the documents have been prepared or are being prepared and in some cases the need for these standard U.S. documents is being debated. The U.S. Army Air Defense School (USAADASCH) is continuing to staff and update the U.S. MEADS ORD. An attempt was made in 1998 to eliminate the ORD in favor of the ICOR, however, this was not successful and the MEADS ORD remains a key U.S. acquisition document. The Command, Control, Computers and Intelligence Support Plan (C4ISP) is being developed by the U.S. MEADS NPO. This document will support development of an international version that is being considered for development by NAMEADSMA. A common test plan will be developed by NAMEADSMA that although not called a Test and Evaluation Master Plan (TEMP), is hoped will satisfy the U.S. acquisition process and the acquisition processes for all national participants.

The bottom line for U.S. acquisition review prior to the next program phase of the MEADS program is that the process will be difficult and close cooperation will be needed between the U.S. MEADS NPO and NAMEADSMA. Fortunately, a foundation of cooperation and collaboration is developing within the TMO arena. There is reason for optimism that the U.S. acquisition process will obtain the information needed to decide whether or not the U.S. will continue participation in the MEADS program into the D&D phase.

E. INTERNATIONAL SPACE STATION (ISS)

Information for the International Space Station TMO discussion is primarily from an interview with Mr. John Winch, who was a Boeing Engineer involved in ISS development from its inception. Mr. Winch’s involvement with the ISS began in 1984 with Boeing proposal work

development of the then U.S. Space Station. In 1987 he became Deputy PM for Boeing's Space Station effort. Boeing had been awarded a contract for one of three major work package contracts for the Station. In 1991 Mr. Winch became PM. After Boeing was selected as prime contractor following reorganization and internationalization of the program in 1995, Mr. Winch continued with his responsibilities in Huntsville for activities related to the original Boeing work package. He retired in 1997.

1. Overview

Figure 19 is a picture of the ISS taken in April of 2001. This image was obtained from the NASA internet Universal Resource Locator (URL) address: <http://spaceflight.nasa.gov/gallery/images/station/assembly/lores/s100e5970.jpg>.

The U.S. began developing what is now the ISS in the early 1980s. Initial efforts were disastrous for a number of reasons that will be discussed later. However, following a reorganization of the effort in 1995, a drastic reduction in scope, the introduction of international participation and heroic efforts on the part of many people, the ISS is now in space.

The International Space Station is the largest and most complex international scientific project in history. And when it is complete just after the turn of the century, the station will represent a move of unprecedented scale off the home planet. Led by the United States, the International Space Station draws upon the scientific and technological resources of 16 nations: Canada, Japan, Russia, 11 nations of the European Space Agency and Brazil (http://www.shuttlepresskit.com/ISS_OVR).

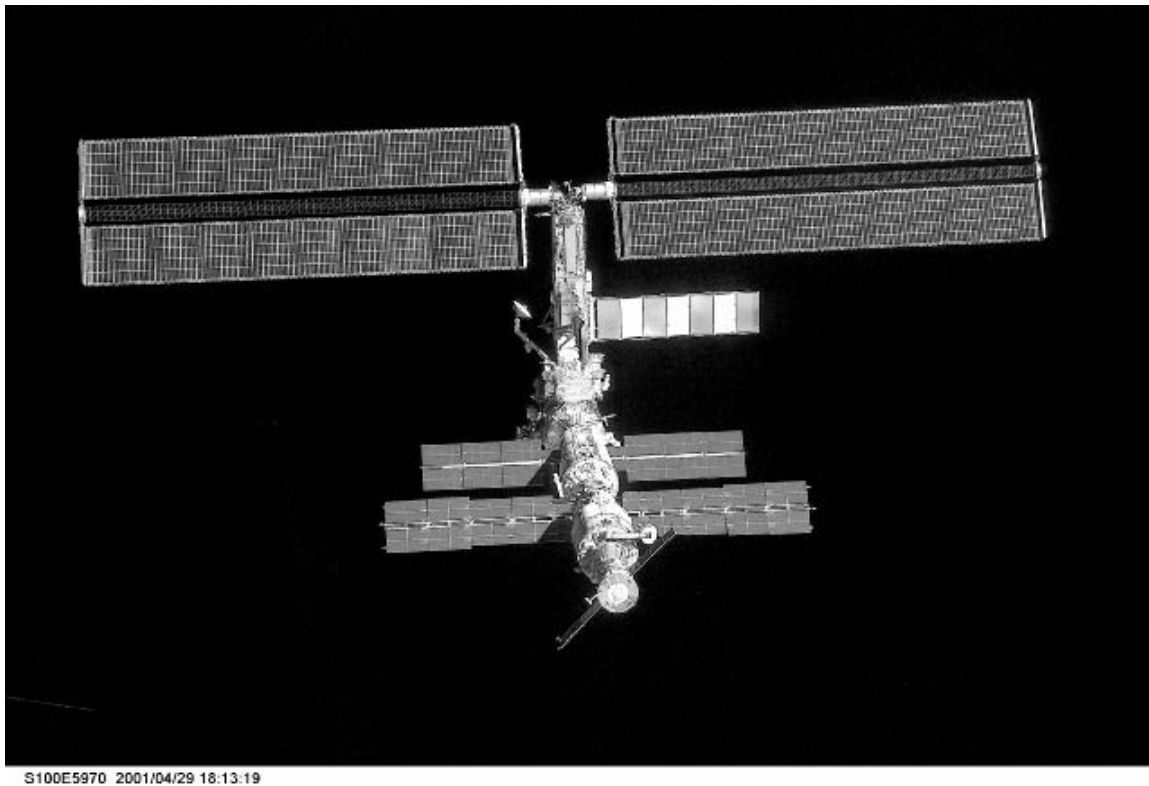


Figure 19: International Space Station (from http://www.shuttlepresskit.com/ISS_OVR)

Without international participation, it is unlikely that the international space station could have been developed. Each participant has had and continues to have funding difficulties as each body politic struggles with priorities. Nations pride, and a deep-seated human interest in space keep the program going. Existing or planned elements of the ISS are described below.

The U.S. elements include three connecting modules, or nodes; a laboratory module; truss segments; four solar arrays; a habitation module; three mating adapters; a cupola; an unpressurized logistics carrier and a centrifuge module. The various systems being developed by the U.S. include thermal control; life support; guidance, navigation and control; data handling; power systems; communications and tracking; ground operations facilities and launch-site processing facilities.

The international partners, Canada, Japan, the European Space Agency, and Russia, will contribute the following key elements to the International Space Station:

- Canada is providing a 55-foot-long robotic arm to be used for assembly and maintenance tasks on the Space Station.
- The European Space Agency is building a pressurized laboratory to be launched on the Space Shuttle and logistics transport vehicles to be launched on the Ariane 5 launch vehicle.
- Japan is building a laboratory with an attached exposed exterior platform for experiments as well as logistics transport vehicles.
- Russia is providing two research modules; an early living quarters called the Service Module with its own life support and habitation systems; a science power platform of solar arrays that can supply about 20 kilowatts of electrical power; logistics transport vehicles; and Soyuz spacecraft for crew return and transfer (www.shuttlepresskit.com/ISS_OVR).

In addition, Brazil and Italy are contributing additional equipment to the station, including the Italian Logistics Module “Leonardo” that recently gained international acclaim.

2. Application of the TMO Framework

a. TMO Considerations

Table 15 captures the ISS TMO Consideration elements.

Table 15: ISS TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	The ISS organization started out as a distributed US activity that included 3 major subsystem developments. with no central management control. This was disastrous and led to restructuring. The new structure was international, including the U.S., Russia, the European Space Agency, Japan and others. NASA remains responsible for coordinating operations, however, Boeing is responsible for all technical coordination and control of the major system interfaces. Each partner is fully responsible for detailed specifications, funds, designs and the product agreed to. Internationally, the organization is loosely coupled with partners having distinct and clearly defined responsibilities that are product oriented.
2. RDEC/ Contractor Technical Support	Government Lab/Contractor Technical Support is critical to the NASA ISS role of oversight, management of technical risk and general technology support. NASA does not involve foreign support-contractors, that is left up to the participating partner nations. Similarly, the foreign partners have no issue with support contractors that NASA uses to provide technical support.
3. Management of Technical Requirements	NASA sets the basic requirements. Boeing maintains the day to day control of interfaces went through Boeing. Boeing also developed a System Specification to ensure a common understanding of the system requirements. Lower level specifications, such as for the solar panel arrays were also firmly controlled. International considerations for requirements center primarily on the docking interfaces and the interface of ISS components to the Space Shuttle, for those components to be transported by the Space Shuttle. Requirements such as safety, reliability, strength, vibration and stiffness were suggested to partners for use with their systems, however, specification responsibility for modules developed by partners such as the European Space Agency, Russia and Japan rests with the developing partner.
4. Management of Technical Risk	Management Technical Risk is done by Boeing and independently by the partner nations. However, NASA maintains oversight of safety and reliability for all elements of the ISS. During the Mercury, Jupiter and Apollo space programs, NASA achieved success by emphasizing safety and reliability. This emphasis was reduced when routine Space Shuttle operations began. However, the Space Shuttle Challenger accident was a reminder to NASA that space operations are inherently dangerous. Today, safety and reliability are key foci of risk management for NASA.
5. Technical Monitoring Capability	NASA technical oversight is heavily focused on safety and reliability. NASA is responsible for overseeing the contracts it lets with Boeing, however, Boeing is pretty free to act within the bounds of the ISS contracts. All participants work together as a team. This is possible because of the pride that individuals take in their participation in the grand adventure of space.

Table 15: ISS TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
6. Direct Technical Contribution	Direct Technical Contributions are made by NASA and all participants based on the roles they play. NASA provides facilities for Testing components, launching rockets and launching the Space Shuttle. NASA also develops candidate technologies and processes that may be used on the ISS. NASA provides the services of experts when needed by Boeing and the other participants. Other Governments participate in the development of their ISS components as they see fit. All participants are highly motivated to succeed.
7. Control of and Access to Technical Data	The policy of NASA for open flow of information relative to the ISS includes Government generated information and to a very large extent, there is no proprietary data used for the ISS. Almost all Government and contractor information is freely available to anyone with a legitimate need for access.
8. User Participation	The concept of User Participation may not apply to development of the ISS, because there is no entity called the User for any NASA development activity. NASA both develops the requirements and then executes contracts to develop the system. The astronauts are to NASA and the ISS like soldiers are to the Army in that astronauts will use the ISS. They influence Human System Interface (HSI) issues.
9. Cost Share and Work Share	Cost Share and Work Share is not an issue for the ISS. Nations pay for the ISS components they are responsible to produce. There is no sharing of development costs in that sense. Canada paid for the development of the ISS robotic arm. Russia paid for the service module, the European Union is paying for development of the European Space Agency's laboratory and Japan is paying for development of its laboratory.
10. Preparation of Contract SOWs	j. There are no special international considerations for the Preparation of Contract Statements of Work (SOW) for the ISS. Each participating country makes its own arrangements with its industry for work to be performed.

b. TMO Program Feedback Considerations

Table 16 captures the ISS TMO Program Feedback elements.

Table 16: ISS TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	There is no international executive control of the ISS per se. NASA controls development of the ISS, and it is purely through good will and common interest that enables international participation.
2. TMO Funding	TMO Funding is split off of the overall program funds to support NASA oversight of Boeing and the international partners efforts. Safety and reliability are important focus areas for NASA and thus receive a good portion of the NASA TMO funds.
3. National Interaction	Related to TMO, this involves primarily reliability and safety. Most of the details of specification and design that are of interest to the U.S. are delegated to Boeing.
4. US Acquisition Review prior to next phase	U.S. Acquisition Review Prior to the Next Program Phase does not apply to the ISS.

3. Elaboration

a. ISS TMO International Organizational Aspects

The original Space Station began in the mid 1980s almost exclusively as a U.S. program. The original program was a disaster that resulted from inappropriate program structure and unaffordable requirements that constantly changed. Initially the program was set up as a U.S. program with three major work packages. NASA's Lewis Center in Cleveland, Ohio managed a contract with Rockwell's Rocketdyne Division. NASA's Johnson Center in Houston, Texas managed a contract with McDonald Douglas and NASA's Marshal Center in Huntsville, Alabama managed a contract with Boeing. The effort was supposed to be integrated and coordinated from NASA facilities in Reston, VA, who used Grumman for a support contractor. The only problem was, the Reston activity had no control. This was a recipe for confusion. This was a recipe for disaster. Spiraling costs and a growing sense that the program

was out of control led to restructuring of the program and internationalization of the program.

In 1995 Boeing was given the Prime Contract for the reorganized International Space Station. Boeing was expected to rationalize the program, identify a set of achievable requirements, establish control of the interfaces, coordinate with international partners, and make this all happen with the yearly fluctuating budget provided by congress. NASA remained in nominal overall control, establishing the contract requirements with Boeing. However, no central international coordinating body was established between Governments.

Next to the United States, the most prominent international participant in the ISS development was Russia. Bringing the Russians into the activity seemed purely political, at the time. However, they brought a lot of knowledge and ability to the program. There were good working relationships between the Russians and the Americans. The main difficulty that emerged was the difficulty Russia had in meeting its commitments to deliver hardware. This was a funding issue, however, and not an organizational issue.

After Russia, the most visible participants in ISS development are the Germans, Italians and Japanese. They have shown a strong desire to participate actively, and they are very capable. The Italians developed the pressurized logistics module that can be transported via the space shuttle and re-used, and this has already played an important role in outfitting the ISS and making the ISS habitable.

Organizationally, all who participate in the ISS development are members of a team with clearly established responsibilities. NASA maintains a contract with Boeing that has a Statement Of Work (SOW) flexible enough to adjust according to annual funding. Portions of the ISS are developed by Boeing and subcontractors. The international

partners independently manage development of any ISS modules they have agreed to develop. NASA's role in the execution is contract oversight, providing launch and test facilities, technical consultation for materials and processes, and oversight of technical risk. The team works because everyone knows their role and everyone wants to succeed.

b. Discussion: ISS Management of Requirements

Initially the intended use of the Space Station was poorly defined, but it was required to be everything to everybody. This proved to be too much to accomplish and too expensive. So it had to be scaled back continuously over the years. There was cutback after cutback after cutback. After Boeing was made prime contractor for the entire project, the situation improved.

In terms of fundamental requirements, NASA still sets the basic requirements. However, following selection of Boeing as the prime contractor, the day to day control of interfaces went through Boeing. And, although not required to, Boeing developed a System Specification to ensure a common understanding of the system requirements. Lower level specifications, such as for the solar panel arrays were also firmly controlled.

International considerations for requirements centered primarily on the docking interfaces and the interface of ISS components to the Space Shuttle, for those components to be transported by the Space Shuttle. Requirements such as safety, reliability, strength, vibration and stiffness were suggested to partners for use with their systems, however, specification responsibility for modules developed by partners such as the European Space Agency, Russia and Japan rests with the developing partner. Boeing maintains control of the docking interface and the interface of ISS components to the Space Shuttle. To ensure absolute adherence to the docking interface, Boeing provides the

actual docking interface hardware to the partner nation for use on the actual ISS module. The partner then must integrate (weld) the docking interface into the ISS module being developed.

c. Discussion: Control of and Access to Technical Data

Control of and access to technical data is different for development of the ISS than for development of military systems. The effectiveness of military systems sometimes depends a great deal on depriving the adversary of technical details about the system. A military system is potentially more vulnerable if an adversary knows how the system works and its weaknesses. The ISS, and other NASA systems, on the other hand are not military systems and are not been developed with the idea of having to survive an attack. NASA does not withhold information. NASA has a policy of openness that is sometimes close to being in conflict with the State Department export policies.

Sometimes export policies of the U.S. have been cause for Boeing to avoid direct transmittal of data to companies in other countries. Often, NASA has acted as the intermediary to enable the transmittal of critical technical information.

F. MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) TERMINAL GUIDED WARHEAD (TGW)

Information for this discussion is primarily from an interview with Mr. Dennis Vaughn, who was worked on the MLRS program for 8 years as the Division Chief for Product Assurance and Test (PA&T) and then for 12 years as the MLRS Deputy Program Manager (DPM). While PA&T Division Chief Mr. Vaughn was also chairman of the MLRS multinational test working group.

For the purpose of discussing TMO, this section focuses on the MLRS TGW warhead development. However, some comments are

directed at the overall MLRS program for context or as information that may be of value.

1. Overview

Figure 20 is an image of an MLRS rocket being fired from an M270 rocket launcher.



Figure 20: MLRS Rocket Firing (from <http://www.redstone.army.mil/history/systems/MLRS.html>)

The Multiple Launch Rocket System (MLRS), formerly known as the General Support Rocket System (GSRS), is designed to supplement cannon weapons available to U.S. Army division and corps commanders for the delivery of a large volume of firepower in a very short time against critical, time-sensitive targets. MLRS is a free-flight artillery rocket system that greatly improves the conventional, indirect fire capability of the field Army. The system provides counter-battery fire and suppression of enemy air defenses, light materiel, and personnel targets.

...

23 Jul 80 The governments of the United States, the United Kingdom, Germany, and France signed a formal declaration of intent to participate in the concept definition phase of the terminal guidance warhead (TGW) program [for use with

MLRS]. The primary mission of the TGW would be to provide rapid fire, non-nuclear capability to destroy a wide spectrum of stationary and moving, medium hard to very hard, armored targets. The declaration required that the TGW be jointly developed, with active participation by industries of all four nations
(<http://www.redstone.army.mil/history/systems/MLRS.html>).

TGW was intended to be an autonomous seeking warhead for use with the MLRS rocket. However, TGW development ended following successful test dispense from an in-flight MLRS missile. The program was terminated prior to system maturation and production.

2. Application of the TMO Framework

a. TMO Considerations

Table 17 captures the TMO Consideration elements for MLRS TGW.

Table 17: MLRS TGW TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
1. TMO Organizational Aspects	The TGW effort was a U.S. led co-development effort involving shared responsibility within the Program Office from the participating nations: the United Kingdom (UK), Germany (GE), France (FR) and the United States (US). The TGW product office consisted of Associate Product Managers (APMs) from each participating nation, with technical staff including engineering, test and logistics personnel from each participating nation. The APMs all reported to the PM for MLRS, who was a US Colonel. Each participating country maintained an MLRS Program Office for internal national coordination. The MLRS TGW Executive Management Committee consisting of the National PMs for MLRS and the Training and Doctrine Command (TRADOC) System Manager or his equivalent User representative was the primary international coordinating body for MLRS TGW. The Executive Management Committee was chaired by the U.S. PM for MLRS, although each member was of equal status for decision making. In turn, the Management Executive Committee reported to the MLRS Joint Steering Committee, which was a two-star board of directors providing international executive oversight over the MLRS TGW program.

Table 17: MLRS TGW TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
2. RDEC/ Contractor Technical Support	Technical Support was critical to the conduct of the MLRS TGW development effort. The key to enabling this support was an activity in the MLRS program office to manage overall cost share and work share. This allowed the PM MLRS flexibility to arrange for technical support from a variety of sources.
3. Management of Technical Requirements	Establishing the initial requirements for MLRS TGW was difficult and required a great deal of time. Agreeing to targets for the system was the biggest difficulty. Once the initial requirements were set liaison , the management of change to specifications was managed through each nations Associate Product Managers, who understood the type of changes that could be agreed and those that would require extensive international coordination.
4. Management of Technical Risk	Management of Technical Risk involved periodic cost/schedule/technical risk assessments. In some cases, competing designs were carried forward to selected decision points. Day to day activities in Huntsville involved technical reviews and interchanges with the prime contractor and major subcontractors. The APMs for each country went through the program from top to bottom on behalf of their nation to provide feedback to their national PM regarding significant technical risk. Millimeter Wave technology was a major risk for TGW. The basic millimeter wave technology was brought in by Germany. The US brought in IR technology which also contained significant risk.
5. Technical Monitoring Capability	Technical Monitoring Capability was divided between RDEC, labs within other nations, and contract support. For technical oversight involving test, there was a good degree of involvement from all participating nations.
6. Direct Technical Contribution	Engineers, testers, and logisticians from the MLRS Program Office made Direct Technical Contributions. The US unique contributions were related to requirements, the selection of targets and system evaluation. The US unique activities were essential to establishing the US position for requirements discussions and definitions of SOWs. In general, all parties brought competent and aggressive technical talent to TGW. The difficult part of this was the time required to address everyone's concerns. The value of having smart people doing TMO is identification of problems that might not otherwise be found. The difficulty is that some of the problems found are not problems. Addressing them takes time and energy away from solving the real problems.
7. Control of and Access to Technical Data	For MLRS, the participating nations all brought valuable information into the program, and technology transfer of sensitive U.S. technology did not become an insurmountable problem. Two specific difficulties: (1) Establishing access in U.S. contractor facilities for non-U.S. people. (2) Establishing a process for transmitting electronically or through the mail classified and sensitive programmatic and design information.

Table 17: MLRS TGW TMO Considerations Framework Elements

TMO Consideration	Interview/Assessment
8. User Participation	<p>User Participation was critical for MLRS in general and for TGW, particularly for establishing the basic TGW system requirements and target characteristics. Each country was represented on the TGW Executive Management Committee by the country PM and TSM level User representative. This solid connection to the user communities enabled difficult issues to be addressed relatively quickly.</p> <p>One issue revolved around facilities for depot maintenance. Common logistics support was established for MLRS in Europe. This worked well for the US due to the heavy US presence in Germany. However, for the US to use the European repair facility, effective configuration control of components was essential. The approach proved effective. During Desert Storm, the US and European units were able to use the same spare parts.</p>
9. Cost Share and Work Share	<p>Cost Share and Work Share portions for TGW were agreed upon in the TGW MOU. They were US: 40%; GE: 20%; FR: 20%; UK: 20%. For cost share, the national currencies were “Pegged” at some initial equivalence, and then this equivalence was used throughout the TGW activity. Work share was more difficult to manage, because expertise was not evenly distributed and companies were cautious about revealing their trade secrets. Additionally, distributing work geographically incurred penalties because of distance and the difficulty in communicating over long distances.</p> <p>The prime contractor, an international consortium, was responsible for managing work share for the contracted effort. PM MLRS was responsible for managing overall work share. It was recognized early that work share would not always be in balance. A work share problem from one development phase could be addressed in the next. Ultimately, imbalances remaining once production began could be addressed by adjustments to third party sales. Duplicate MLRS production lines had been set up in the U.S. and in Europe.</p>
10. Preparation of Contract SOWs	<p>Discussion: Preparation of Contract Statements of Work (SOW) was time consuming and required great effort on the part of all participants. The TGW SOWs were of great interest to each national PM, and obtaining agreement for the content of the SOWs at the National PM level was essential, although laborious.</p>

b. TMO Program Feedback Considerations

Table 18 captures the TMO Program Feedback elements for the MLRS TGW program.

Table 18: MLRS TGW TMO Program Feedback Framework Elements

TMO Consideration	Interview/Assessment
1. International Executive Control	The Joint Steering Committee did not get directly involved in the day to day decisions and coordination that was necessary between nations. This coordination was performed by the TGW Executive Management Committee. When issues arose that the executive management committee was not empowered to address, they were raised to the level of the Joint Steering Committee.
2. TMO Funding	b. TMO Funding was managed by the PM within the context of Cost Share and Work Share. The main thing was to balance the overall work share in line with cost share, however, and TMO was only one element considered when balancing cost share and work share. Some funding was allocated by PM MLRS for US unique activity which was accounted for and managed separately.
3. National Interaction	National Interaction with the US bureaucracy involved dealing with people who were detractors and those who were proponents. Generally the detractors have difficulty dealing with international programs because they fall outside of establish procedures for security and accountability. With TGW, people in the US acquisition process had not yet become accustomed to working with international programs. “Decision makers in the US cannot go to the PM and demand something in particular. The US PM has to go to the international program partners and consult. Sometimes the US decision makers are looking for a direct answer (Dennis Vaughn Interview, 16 August 2001).”
4. US Acquisition Review prior to next phase	The U.S. acquisition review process was essentially the same for MLRS as for other U.S. acquisition programs. The difference was that an attempt was made to minimize the duplication of documentation needed by each country’s acquisition process. For example, the Test and Evaluation Master Plan (TEMP) was expanded to include consideration for European testing and the needs of GE, FR and UK decision makers. The Acquisition Strategy document required by the U.S. acquisition process, was too different than what was needed by the European acquisition processes. Excerpts from the US document were used to satisfy European acquisition needs, however, the US document was maintained separately.

3. Elaboration

a. TMO International Organizational Aspects

The TGW development effort was conducted within the framework of the existing MLRS program structure. A separate MOU

was created for TGW, however this MOU was written to be consistent with the basic MLRS MOU. The MLRS international relationships are depicted in Figure 21.

The TGW effort was a co-development effort involving shared responsibility within the Program Office from the participating nations: the United Kingdom (UK), Germany (GE), France (FR) and the United States (US). The TGW product office consisted of Associate Product Managers (APMs) from each participating nation, with technical staff including engineering, test and

logistics personnel from each participating nation. The APMs all reported to the PM for MLRS, who was a US Colonel. Each participating country maintained an MLRS Program Office for internal national coordination. The MLRS TGW Executive Management Committee consisting of the National PMs for MLRS and the Training and Doctrine Command (TRADOC) System Manager or his equivalent User representative was the primary international coordinating body for MLRS TGW. The Management Executive Committee was chaired by the U.S. PM for MLRS, although each member was considered of equal status for decision making. In turn, the Management Executive Committee reported to the MLRS Joint Steering Committee, which was a two-star board of directors providing international executive oversight over the MLRS TGW program.

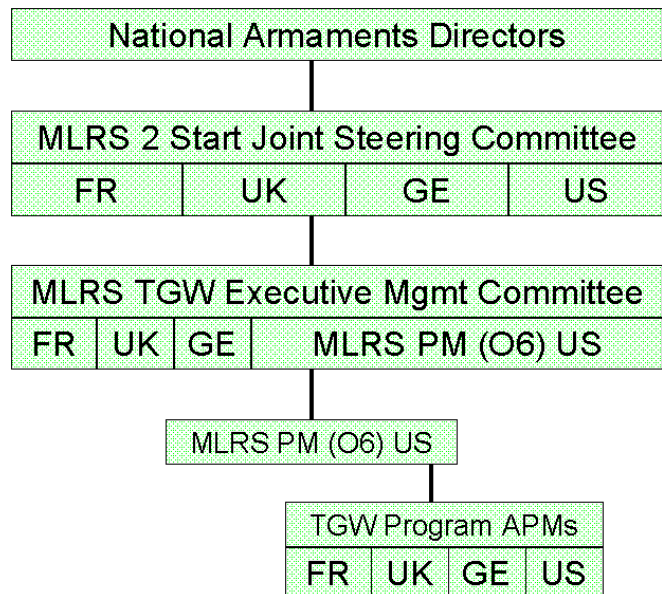


Figure 21: MLRS Management (from interview with Dennis Vaughn)

b. Discussion: RDEC/Contractor Technical Support

RDEC/Contractor technical support was critical to the success of TGW development. Not the least of this technical support provided by RDEC involved a Hardware In the Loop (HWIL) facility that was used by both the developing contractor and the MLRS Program Office. Technical support came in two flavors for MLRS TGW. There was technical support paid for solely by the U.S., and there was technical support subject to cost share and work share. PM MLRS had authority to establish TGW support activities, with the caveat that the overall work share was supposed to remain balanced for support that applied to partner nations. Surveys were made to find potential sources for support in the participating nations. The goal was to give each country a fair share based on the overall MOU cost share/work share agreement. However, there was no special cost share/work share pool that had to be balanced for contract technical support. The requirement was to balance the overall cost share/work share for TGW. It was recognized early on in MLRS that the PM needed to have the authority to make decisions, ... and he did make decisions. Many times there were sessions of the MLRS Executive Management Committee to debate and ratify these decisions. National interests were involved, but it was also recognized that the program needed to move forward and that compromise was necessary.

c. Discussion: Management of Technical Requirements

Management of technical requirements for TGW was difficult in terms of establishing the initial TGW requirement. Much of the difficulty centered around target selection and characterization of the target selected. This, in turn, led to difficulty in the selection of the technology to use. TGW was an autonomously guided warhead that relied upon the target's fundamental physical characteristics for terminal guidance.

Each nation's Users were actively involved in establishing the basic requirements, and each used similar processes.

When you really get down to the details, each of the nations goes through the same process to arrive at a system. The users define the need, negotiate with the developers on what is achievable to arrive at a system requirement, no matter what name you call it. (Dennis Vaughn Interview, 16 August 2001)

For managing the requirements, the TGW Executive Management Committee addressed the top level requirements at a level that would be similar to the US ORD level. A system specification was published to reflect the common requirements of the Users from UK, GE, FR and US. Any changes to this system specification required agreement by the TGW Executive Management Committee.

Requirements allocated to lower level specifications were generally addressed within the MLRS Program Office by national APMs or engineers who were expected to speak for their countries, and they were expected to know when to coordinate with their National PMs. Electronic Configuration Management (CM) was used. Local people in the Huntsville MLRS Program Office sat on the TGW CM board.

It ran pretty smoothly. There were hard arguments for hard issues, but, things ran pretty smoothly (Dennis Vaughn Interview, 16 August 2001).

d. Discussion: Technical Monitoring Capability

Technical monitoring capability was divided between RDEC, labs within other nations, and contract support. For technical oversight involving test, there was a good degree of involvement from all participating nations.

There was a degree of competition between test ranges in the different partner nations. Where was the most effective place to do this testing? Everything from component and

environmental testing to flight testing. The first factor considered was 'How effective would the test facility be?' The second factor considered was work share. Components, test equipment, analysis, ... these things were spread around. And then there was the ordnance board and the safety board (Dennis Vaughn Interview, 16 August 2001).

e. Discussion: Control of and Access to Technical Data

Control of and access to technical data was an important difficulty to overcome. Concern for control of information exchanged between contractors and between Governments is less in Europe than in the US, because European nations are more accustomed to cooperative development effort.

Visa/Working/Security arrangements at the start were very difficult. Trying to set up in the industry for foreign nationals to come to Orlando or Dallas and have the freedom to come and go and to open a file cabinet took, ... in some cases, a long time. There are a lot of rules in the US that are not geared for multinational programs. ... Or, it was a problem if someone critical to the program had a visa run out and he had to go back to Europe (Dennis Vaughn Interview, 16 August 2001).

Secure communications between PMs and particularly between national PMs in the US and counterparts was difficult. To solve that problem, security equipment was sent to the other offices just get past the compatibility issues. Flow of information in general was difficult. A special office was set up within the MLRS Program Office to handle the exchange of information between countries.

We had a central office in the PM shop that all information flowed through. We were able to use diplomatic carriers and individuals within each contractor that were designated carriers. There were couriers between each country. For any US information to be exchanged, it had to come in through security channels, with proper approval (Dennis Vaughn Interview, 16 August 2001).

f. Discussion: Cost Share and Work Share

Cost share and work share portions for TGW were agreed upon in the TGW MOU. They were US: 40%; GE: 20%; FR: 20%; UK: 20%. For cost share, the national currencies were “Pegged” at some initial equivalence, and then this equivalence was used throughout the TGW activity. The exchange rate was fixed for TGW. Although several attempts were made to change the rates, no change was made while the program was active.

Work share was more difficult to manage, because expertise was not evenly distributed and companies were cautious about revealing their trade secrets. Additionally, distributing work geographically incurred penalties because of distance and the difficulty in communicating over long distances.

The prime contractor, an international consortium, was responsible for managing work share for the contracted effort. PM MLRS was responsible for managing overall work share. It was recognized early that work share would not always be in balance. A work share problem from one development phase could be addressed in the next. Ultimately, imbalances remaining once production began could be addressed by adjustments to third party sales. Duplicate MLRS production lines had been set up in the U.S. and in Europe.

All during the program we tried to balance the work. Sometimes it may not have been the best technical location to do the work (from the U.S. perspective), but if Germany was down in work share, then work might be sent to labs in Germany (Dennis Vaughn Interview, 16 August 2001).

Conversion of currencies for payment of program activities was minimized by establishing a bank in each country for the payment of contractor effort in that country. The PM MLRS maintained records of work performed and issued payment vouchers to the appropriate banks for work performed in FR, GE, UK or US.

As a side note, a follow-on MLRS program called Guided MLRS (GMLRS), does not impose an absolute work share on the partner nations. It is primarily a best value effort. However, GMLRS is a significantly lower cost development than was TGW. It is not certain what motivated the other partners to agree to this best value approach. Certainly the desire for the capability was a factor. The desire to simplify management of the effort and to reduce costs may have also been factors.

g. Discussion: Preparation of Contract Statements of Work (SOW)

Preparation of Contract Statements of Work (SOW) was time consuming and required great effort on the part of all participants. The TGW SOWs were of great interest to each national PM, and obtaining agreement for the content of the SOWs at the National PM level was essential, although laborious.

The requirements and the SOW have to go through individual nation's decision processes. The budget years don't line up. Timing of the decision processes don't always line up. There just was a lot of work and patience required to pound through the arguments. It goes through all of the functional disciplines, a laborious process. It also requires leadership in these working groups and the branches and so forth that can deal with compromises (Dennis Vaughn Interview, 16 August 2001).

h. Discussion: National Interaction

National interaction with the US bureaucracy involved dealing with people who were detractors and those who were proponents. Generally the detractors have difficulty dealing with international programs because they fall outside of established procedures for security and accountability. With TGW, people in the US acquisition process had not yet become accustomed to working with international programs.

Decision makers in the US cannot go to the PM and demand something in particular. The US PM has to go to the international program partners and consult. Sometimes the US decision makers are looking for a direct answer (Dennis Vaughn Interview, 16 August 2001).

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V. ANALYSIS, CONCLUSIONS AND RECOMMENDATIONS

A. OVERALL ANALYSIS, CONCLUSIONS AND RECOMMENDATIONS

The framework depicted in figure 22 has been used to organize information gathered during interviews with senior technical leaders from high profile international programs. This section summarizes the analysis, presents conclusions and makes recommendations.

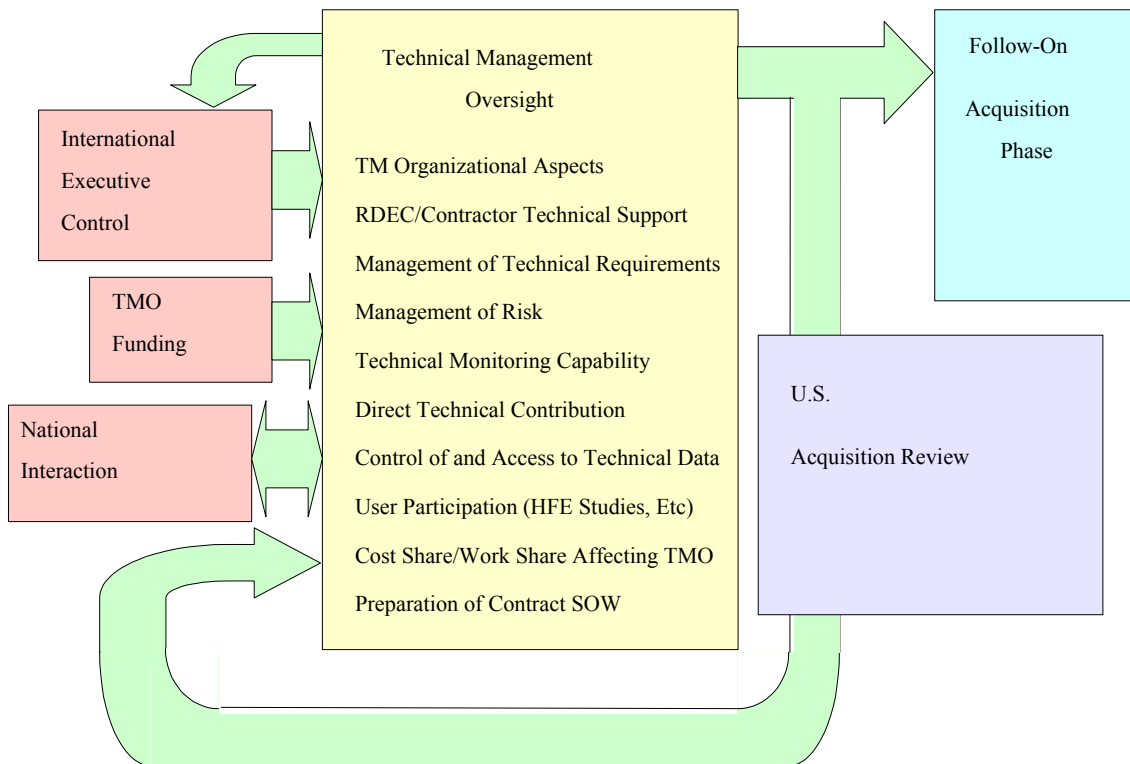


Figure 22: International Technical Management Oversight Framework

1. Overall Analysis and Conclusion for Framework Utility

The TMO framework was effective in structuring data collection for TMO data collection and study of international programs. The TMO framework elements were found to have various degrees of utility. A criterion called “coupling,” emerged from the analysis, that correlates to the utility of some framework elements for particular programs. Tight coupling exists for a program if significant international coordination is

required for program execution. This situation existed for the MEADS and the MLRS TGW programs. Loose coupling exists for a program if minimal international coordination is required. This framework for evaluation of international programs is most effective for tightly coupled international programs.

Figure 23 depicts the composite utility of each TMO framework element assessed. The detailed assessments for each framework element

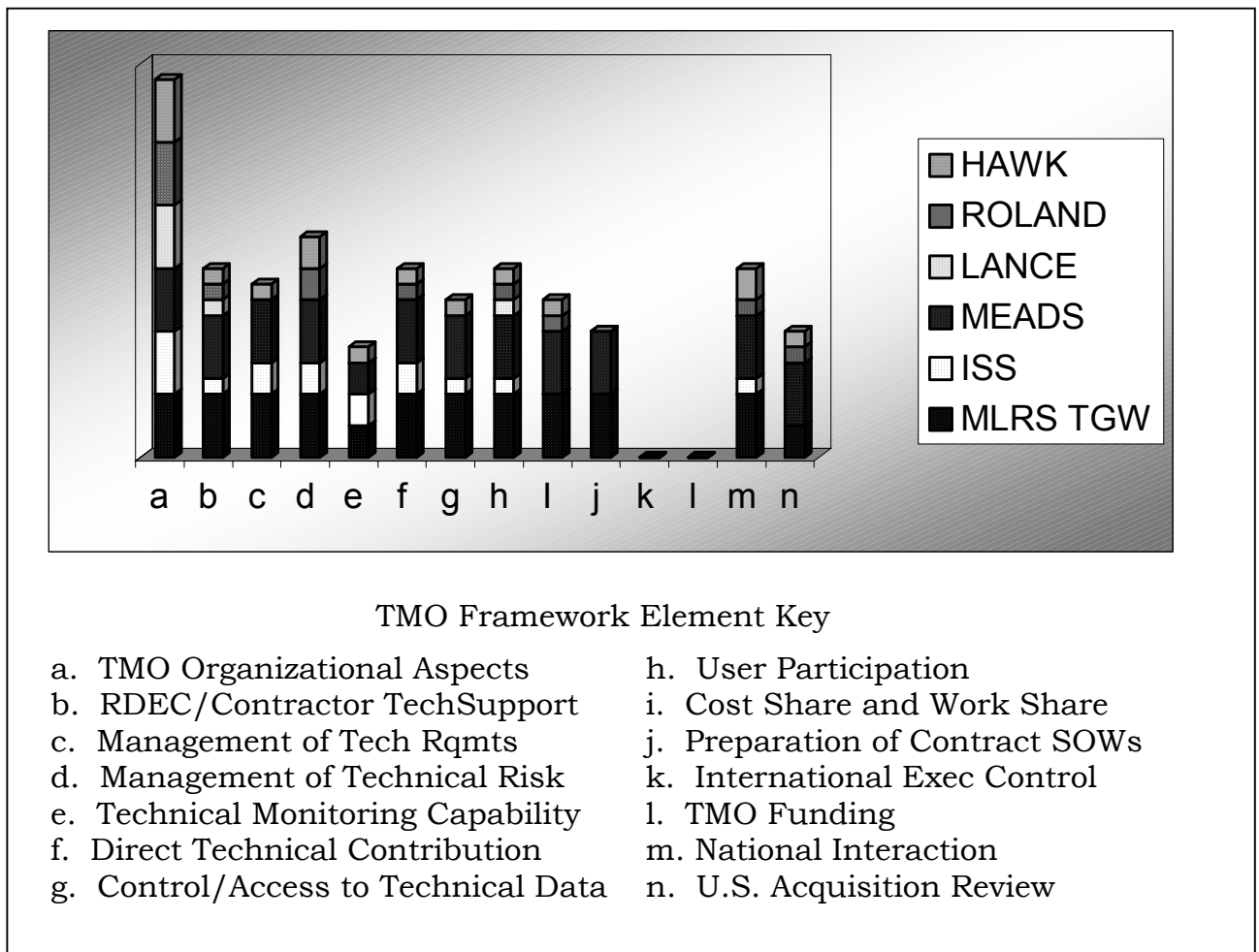


Figure 23: TMO Framework Element Utility

can be found in section B of this chapter. As suggested by Figure V – 2, “TMO Organizational Aspects” is universally applicable. That is because the organization description characterizes each program as tightly

coupled or loosely coupled, which becomes a predictor of how useful this framework is for describing an international program.

Two elements are shown to have no value for this framework. This is because the information that would be collected in these elements is already collected in other elements. The International Executive Control element corresponds to the TMO Organizational Aspects element. The TMO funding element corresponds to the Cost Share Work Share element. Another element that may be redundant is the Technical Monitoring Capability element. This element overlaps with the RDEC/Contractor Technical Support element. Overall, it appears the TMO framework has value for description and study of a range of international programs, but the greatest utility is for the description and study of tightly coupled international programs.

2. TMO Conclusions

This paper proposes a framework for capturing and studying TMO insights for international programs. Interviews were conducted with key program personnel from several programs to populate the framework with program data. Programs considered were HAWK, ROLAND, LANCE, MEADS, the International Space Station, and MLRS TGW. These programs had various degrees of international participation. Valuable insights were captured that can be applied to the structure and conduct of ongoing and future international programs.

From the information collected, specific conclusions can be made regarding international programs:

- TMO Organizational Aspects
 - The organization structure and rules for change strongly impact TMO.
 - Coupling within international programs affects management complexity.

- There may be a relationship between the degree of coupling of international programs and program success, but this was not verified with data.
- RDEC/Contractor Technical Support
 - TMO Technical Support is crucial for international programs.
 - Support is needed to ensure contractor accountability, to do requirements analysis, to aid in technology transfer, to make direct technical contributions and to represent the Users interests.
 - When cost share and work share are considerations, they must be applied to Technical Support
- Management of Technical Requirements
 - Knowing who the customer is, is important (Collectively the Users of the participating nations).
 - Requirements analysis and update is more difficult for an international program and the difficulty increases with the number of participants.
 - Early establishment a process for clarification and update of requirements is important.
 - Local national representatives should be empowered to approve requirements changes and specification changes that do not affect the major performance requirements of the system.
 - Stabilizing of requirements before starting a major international development is desirable. If changes are necessary, they should be done prior to start of a focused development activity.
- Management of Technical Risk
 - Risks should be identified and acknowledged, but diplomacy is important
 - There is risk integrating systems developed outside the U.S. into U.S. Systems and this risk should be managed (see ROLAND write-up).
 - For tightly coupled international development programs, technology transfer risks must be aggressively managed. Some independent US action should be expected if full disclosure of information is not provided.

- Technical Monitoring Capability
 - Establishing an effective TMO presence as a legitimate part of the Contractor/IPO/Government development effort will pay big dividends.
 - Diplomatic communication is important when one country monitors/reviews another countries contractors
 - Responsibility for oversight of a nations contractors can be effectively accomplished by representatives of that nation. (See write-up for MLRS TGW)
- Direct Technical Contribution
 - TMO direct technical contributions are crucial for program success
 - Areas for TMO direct technical contribution include requirements analysis, trade studies, coordination of technology transfer, simulation, performance evaluation, interoperability, human systems integration, and whatever expertise people have in the IPO and in the NPOs.
 - IPO and NPO can become too involved and add schedule risk
- Control of and Access to Technical Data
 - Effective configuration management of internal program data is crucial. National representatives within an IPO should be empowered to authorize changes not affecting major performance requirements of the system.
 - Tightly coupled international programs that require access to tightly controlled technical data require special management attention, especially from the nation that is controlling the information.
 - Clear Technology release policy is crucial.
 - Consistency in the release and control of information from one nation to others is extremely important. Once data of a certain type has been released, it is understandable why national representatives are offended when information of that type is withheld later. International incidents may be generated if this occurs.
 - False impressions of future information release must be avoided. The risk of potentially not getting release should be understood.

- Arrangements need to be made for efficient transfer of classified and unclassified program information, both electronically and hardcopy, to and from the participating nations.
- User Participation
 - User participation is important for the clarification of requirements, human system integration trade studies and test
 - Participating Nations have different views on the degree of User participation.
- Cost Share and Work Share
 - It is possible to manage overall work share in a way that allows access to participating government's Labs and agencies (See MLRS TGW write-up) as well as to support contractors
 - An agreement to allow balancing of work share in subsequent program phases can be very helpful and give the IPO much needed flexibility for TMO.
- Preparation of Contract Statements of Work
 - Each participating nation must put an SOW for system development through its national decision processes, making the process for developing and approving SOWs very time consuming.
 - Having senior people involved in SOW development with the capability to make sensible compromises is extremely valuable
 - A bad international SOW is not more likely to gain approval as it ages.
- National Interaction
 - Patience and diplomacy are important
 - Release requirements for information complicate National Interaction
 - Management attention is needed in US involvement in International programs to educate participants in the US acquisition process about the uniqueness of international programs.

- U.S. Acquisition Review Prior to the Next Program Phase.
 - U.S. Policy for acquisition review has not caught up with international programs and needs to be updated following serious debate about priorities and technology transfer policies.

3. TMO Recommendations

- For future international programs, consider minimizing the international coupling of the programs so that the need for international coordination is minimized, organizational friction is reduced and each partner is able to understand the national role in the development program.
- Initiate a debate within the U.S. about the degree to which the U.S. will participate in future international programs that necessitate release of sensitive U.S. data.
- For future international programs, ensure adequate processes are established prior to program initiation to manage cost share and work share to enable access to national laboratories, support contractors, prime contractors and subcontractors.
- Know the customer.
- Train all participants in international programs how to be diplomatic in communicating to international counterparts.
- Anticipate and plan for U.S. specific activity in tightly coupled international programs that involve use of sensitive U.S. data.
- For future international programs, plan technical staff for both international and U.S. specific activities to address technical issues that are out of reach of the prime contractor.
- For future international programs, plan resources to support technology transfer and to obtain approvals to release U.S. information into the international program.
- For future international programs, make plans for courier and electronic transfer of classified and unclassified program information between all parties.
- Plan to balance work share across program phases to improve TMO flexibility.
- Plan adequate time for preparation and approval of international SOWs.

B. TMO FRAMEWORK ELEMENT ANALYSIS

1. TMO Considerations Framework Elements

a. TMO International Organizational Aspects

(1) Framework Element Analysis. The International Organizational Aspects TMO Framework Element has high value. With information from this element it was possible to classify programs according to degree of international involvement, method of involvement, and degree coupling of international partners. Describing a program as “Tightly Coupled,” such as for the MEADS program, suggests that program success is highly dependent upon successful coordination between the international partners. Describing a program as loosely coupled, such as for the International space station, suggests that the program can be successful with minimal coordination between national partners. Table 19 lists the programs, suggests classification of the programs and suggests a high value for this framework element as applied to each of the programs reviewed.

(2) TMO Lessons Learned. The programs reviewed had varied international organizational aspects. From the information gathered in chapter IV, it can be surmised that the degree of international involvement does not impact program execution nearly as much as the method of involvement and the degree of coupling between international partners in the management of the program. It is apparent that tightly coupled international programs are more organizationally complex than loosely coupled international programs. The organization structure and rules for change strongly impact TMO.

Table 19: TMO International Organizational Considerations

TMO Framework Element: TMO International Organizational Considerations			
<u>PROGRAM</u>	<u>PROGRAM CLASSIFICATION</u>	<u>VALUE</u>	<u>COMMENT</u>
HAWK	US Developed (Almost No coupling) With Foreign Sales and Production	HIGH	This element can be used to characterize the nature of the program being considered. The programs. Information collected in this framework element was distilled to create the Program Classification Column in this table.
ROLAND	Foreign Developed (Almost No Coupling) with US Production	HIGH	
LANCE	US Developed (No Coupling) with Foreign Sales	HIGH	
MEADS	Tightly Coupled International Development with Shared Leadership	HIGH	
International Space Station	Loosely Coupled International Development	HIGH	
MLRS TGW	Tightly Coupled International Development with US Leadership	HIGH	

b. RDEC/Contractor Technical Support

(1) Framework Element Analysis. This TMO Framework Element has mixed value for evaluating international programs. The value depends on the organizational aspects of the program. Table 20 summarizes the value of this element for an International TMO Framework considering the six programs reviewed. For programs with tight coupling between international partners, this is a crucial area for management attention. For other programs, the technical value remains high for obtaining competent support, however, for these programs there are few international difficulties related to the support.

Table 20: RDEC/Contractor Technical Support

TMO Framework Element: RDEC/Contractor Technical Support		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	Minimal international considerations. The support provided was crucial, especially for system improvements and failure analysis. After international production began, this technical support was critical for resolving international issues.
ROLAND	LOW	Minimal international considerations, but critical for program, especially in overcoming MTBF and calibration problems.
LANCE	LOW	Minimal international considerations, but critical for program, especially for technology transfer from Government Labs to industry
MEADS	HIGH	Work Share complicates arranging for RDEC or contractor technical support. Work share must be balanced between nations overall, but no mechanism is established for managing work share with RDEC, although arrangements have been made to manage work share for a support contractor. Technology transfer issues make it unclear what kind of support RDEC and support contractors can provide if arrangements are made. For US specific support, RDEC and support contractors are involved through the US NPO, but for this, work share is not a consideration.
Inter-national Space Station	LOW	Each country is responsible for the portion of the ISS that it has agreed to build. Boeing remains responsible for coordinating systems issues, and is able to access the NASA labs for technology and test assistance as needed.
MLRS TGW	HIGH	RDEC was involved in MLRS TGW both for US Specific support and for international support. Work share was a consideration, but a mechanism was in place in the MLRS project office to track work share allocation. Technology transfer issues were addressed effectively, although it was not always easy.

(2) The TMO Lessons Learned from the programs reviewed for the RDEC (or lab, in the case of NASA)/Contractor Technical Support were not surprising. It was confirmed that TMO technical support is crucial for development of complex systems. It is necessary to ensure contractor accountability, to do requirements analysis, to aid in technology transfer, in some cases to find solutions to problems that the

prime contractor is not well situated to solve, and to represent the user. The HAWK, Roland, LANCE and ISS programs did not encounter significant problems related to the international aspects of technical support. Also, the MLRS TGW program successfully engaged the RDEC and technical support community for both US specific and shared international activity. MEADS has been able to engage the support contractor community and RDEC for US specific activity but remains challenged to engaged RDEC for direct support of the international program.

c. Management of Technical Requirements

(1) Framework Element Analysis. This TMO Framework Element has mixed value for evaluating international programs. The value depends on the organizational aspects of the program. Table 21 summarizes the value of this element for an International TMO Framework considering the six programs reviewed. For programs with tight coupling between international partners, management of technical requirements is a crucial area for management attention. For other programs, it remains important to manage requirements effectively, however, for these programs there are few international issues related to requirements management.

(2) The TMO Lessons Learned from the programs reviewed for TMO requirements management for international programs are similar to what is known about major development programs in general. First, the customer must be identified and his/her needs must be addressed. For US programs, the customer is the User who represents the soldiers who will be responsible for the system. For international programs, the customer is collectively the Users of the participating nations.

Table 21: Management of Technical Requirements

TMO Framework Element: Management of Technical Requirements		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	Minimal international considerations. However, stable requirements were especially important once involvement began with the international community.
ROLAND	ZERO	No international considerations. U.S. requirements were the only consideration once the data package was obtained from the Europeans.
LANCE	ZERO	LANCE was a US System sold to Europeans. No international participation with requirements.
MEADS	HIGH	MEADS is a tightly coupled international activity. Obtaining initial agreement on requirements was very time consuming requiring agreement from all parties. As U.S. user requirements have matured, needed clarifications to the international requirements have not kept pace, mostly as a result of needing consensus from partner nations. US user satisfaction with the MEADS system may hinge on effective international TMO of requirements.
Inter-national Space Station	MEDIUM	Each country is responsible for the portion of the ISS that it has agreed to build and is responsible to maintain requirements for the system elements it is developing. Boeing is responsible for maintaining configuration control over key interfaces, such as the docking interface and the shuttle payload bay interface. Boeing remains responsible for coordinating systems issues, and is able to access the NASA labs for technology and test assistance as needed.
MLRS TGW	HIGH	Establishing a set initial requirements was difficult. This applied particularly to the required target set. This led to difficulties selecting technology from that available from the partners. Except for the top level requirements, management of requirements changes, though difficult, was handled locally by empowered national technical representatives.

The requirements analysis and update process, time consuming and cumbersome for US programs, is more difficult for international programs. For international programs, the requirements and changes need to be agreed upon by all parties. Thus, a significant lesson learned is that stabilizing requirements before initiating an international program is important. Also, local country representatives should be empowered to make decisions for change of allocated

requirements that do not change the overall system requirements. It should be understood by all national parties that some requirements will have to be changed or clarified. It is difficult to get all the requirements 100 percent correct at the start of a program. Nevertheless, requirements must stabilize before major requirements allocation and design activity begins, or else uncontrolled cost will result.

d. Management of Technical Risk

(1) Framework Element Analysis. This TMO Framework Element has value for evaluating most international programs reviewed. For LANCE there was no framework value because, the program was managed solely by the US. Table 22 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

For programs with tight coupling between international partners, international considerations for management of technical risk are crucial for management attention. For other programs, there is value because of shared risk and the need to coordinate to address this risk.

(2) The lessons learned for Management of Technical Risk for the programs reviewed are valuable. Participants in an international acquisition program should be prepared to aggressively address technical risk while remaining diplomatic and careful about assigning blame when issues arise. There is risk of integrating systems into the US for systems that were developed and tested elsewhere. For

Table 22: Management of Technical Risk

TMO Framework Element: Management of Technical Risk		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	MEDIUM	International considerations after international production. Program risk continues after production, and when things go wrong, such as missiles blowing up during lot testing, finger pointing may begin, high level national representatives may get involved and the problem resolution made more difficult.
ROLAND	MEDIUM	International considerations involved understanding the European developed processes and designs. Further, Roland was assumed to be a mature system. Some redesign was required to stabilize calibration of the radar.
LANCE	ZERO	LANCE was a US System sold to Europeans. No international participation with risk.
MEADS	HIGH	MEADS is a tightly coupled international activity. MEADS pushes the state of the art for Radar and missile technology, and involves transfer of sensitive U.S. technology. There is risk for successful integration of advanced technology and there is risk related to technology transfer. The system has not yet been developed, and much effort will be required by all to successfully address the risk on this program.
Inter-national Space Station	MEDIUM	Each country is responsible for the portion of the ISS that it has agreed to build and is responsible to maintain manage the risk for the system elements it is developing. The international considerations for risk involve interfaces. Boeing's unique approach providing the physical docking interfaces f between space station modules minimizes some of this concern. Nevertheless, close international cooperation is needed when issues arise to ensure safety.
MLRS TGW	HIGH	The varied nature of potential targets for TGW led to consideration of a variety of technologies, which were available in the different partner nations. While technical considerations were the major risk driver, work share issues had influence, complicating the technical solutions and increasing risk. Technology transfer issues were a factor, but because significant technology was coming from Europe, the risk of US technology transfer was minimized.

this situation, objective testing should be done. For tightly coupled international development activities, it is important to address technology transfer risk. When access is limited, consideration should

be given to independent U.S. action. While not the preferred approach from the point of the international partners, this may be the only viable option.

e. Technical Monitoring Capability

(1) Framework Element Analysis. This TMO Framework Element has value for evaluating international programs, but its value is reduced because of the overlap between this element and the RDEC/Contract Support framework element. Table 23 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

(2) TMO Lessons Learned for technical monitoring for the six programs reviewed are limited because some of the pertinent data was collected under the RDEC/Contractor Technical Support framework element. However, there was a re-emphasis of the importance of communicating diplomatically when U.S. monitoring of partner development is conducted. NASA's experience was that the NASA role of being watchdog for safety and reliability was accepted and NASA personnel and support contractors are accepted as part of the development teams. The MLRS TGW program distributed responsibilities for oversight according to which nation was doing the work, which was effective.

Table 23: Technical Monitoring Capability

TMO Framework Element: Technical Monitoring Capability		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	Some international consideration for technical monitoring. When production problems occurred in US, European production questioned the US provided data package and US consultants went overseas to evaluate. Engineering evaluations became political and had a major influence on HAWK program international efforts.
ROLAND	ZERO	US Program was only concerned with US production and fielding
LANCE	ZERO	100 % US managed effort. TMO Technical Monitoring did not have international considerations.
MEADS	MEDIUM	TMO Technical monitoring is affected by cost share and work share along with technology transfer. There is an overlap between this TMO Framework element and the RDEC/Contractor Support TMO Framework Element, however, and so the value of this framework element is reduced.
Inter-national Space Station	MEDIUM	TMO Technical Monitoring did involve international considerations for ISS, particularly because safety of operations is paramount for NASA. Overlap of this element with RDEC/Support Contractor TMO Framework Element reduces value. Additionally, as the MEADS program progresses past the planning activities and into development, this framework element may increase in value.
MLRS TGW	MEDIUM	This framework element was of value because it brought focus to the distribution of responsibilities for TMO Technical monitoring among the participating nations. However, the value was reduced because of the overlap with another framework element.

f. Direct Technical Contribution

(1) Framework Element Analysis. This TMO Framework Element has value for describing international programs. The value is related to the degree of coupling between partner-nation management processes. Additionally, Table 24 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

Table 24: Direct Technical Contribution

TMO Framework Element: Direct Technical Contribution		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	Little of the HAWK TMO Direct Technical Contribution was international in nature or constrained by the international nature of the program.
ROLAND	LOW	Little of the ROLAND TMO Direct Technical Contribution was international in nature or constrained by the nature of the program.
LANCE	ZERO	TMO Direct Technical Contribution did not have international considerations.
MEADS	HIGH	The value for MEADS is evident for requirements analysis for both US specific effort and international effort. Additionally, effort to develop a comprehensive yet concise SOW for the future D&D development phase will be important. Important contributions related to obtaining approvals for technology transfer are anticipated. In addition, contributions made by RDEC/Support Contractors will be important, but this is described in another area, and so there is overlap between these framework elements.
Inter-national Space Station	MEDIUM	The technical contributions of NASA tended to be in the technology area where the labs were involved and in procedures intended to ensure safety and reliability. However, this framework element overlapped with the RDEC/Support contractor element, minimizing the value of this element relative to the ISS and the TMO framework.
MLRS TGW	HIGH	Personnel from each nation were competent with opinions about the best technical approaches. Having a high degree of talent in the TMO activity was both a good and bad. The good part was that difficult technical issues received a lot of TMO attention, helping to ensure that problems were understood and thoroughly addressed. The bad part about this was that sometimes progress was slowed by the variety of opinions that had to be addressed fairly. Addressing problems that turned out not to be problems took time and energy away from solving real problems.

(2) TMO Lessons Learned for direct technical contribution for the six programs reviewed are that there is high value in technical contributions from TMO personnel for both U.S. and international development programs. For international development programs, work share and technology transfer issues complicate availability of personnel and information, TMO direct technical contributions are crucial for program success. Requirements analysis and SOW preparation are valuable areas for direct technical contribution for international programs. For tightly coupled international programs, work share and technology transfer concerns will complicate this effort. Additionally, TMO interfaces with other programs and agencies can provide valuable direct technical contribution in the identifying of and resolving of issues that are driven by interface to other programs.

g. Control of and Access to Technical Data

(1) Framework Element Analysis. This TMO Framework Element has mixed value for describing international programs. The value relates to the coupling between partner-nation management processes. Table 25 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

(2) TMO Lessons Learned. Control of and access to technical data for international programs with tight coupling is critical. The more information that is exchanged for the execution of a program, the more important effective configuration control is. Also, if any of the participating nations have technology release restrictions, it is important to have clear technology release policy.

A negative lesson learned during the interview process for this research paper, but not attributed to any one program is that consistency is important. Serious problems result if information is

Table 25: Control of and Access to Technical Data

TMO Framework Element: Control of and Access to Technical Data		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	There was little application of this international TMO framework element for HAWK development that was revealed by the interview. Export control decisions had to be made, but they were for the system and specific information needed to field and operate the system.
ROLAND	ZERO	There was no application of this international TMO framework element for Roland.
LANCE	ZERO	There was no application of this international TMO framework element for LANCE that was uncovered by the interview. However, the issues surrounding export control would be worth investigating.
MEADS	HIGH	Configuration Control is expected to be more difficult due to the increased number of stakeholders associated with the system requirements. Procedures will need to be worked out to address this. International aspects of technology transfer have proven tedious, with no guarantees up front about specifically what will or will not be released.
Inter-national Space Station	LOW	The control of specifications and interfaces for the ISS is critical, however, the main common concern is for the interfaces, such as the docking interfaces and the Shuttle payload bay interface for transport of ISS components. As to access to technical information, it is not an issue. NASA has a policy of openly sharing information with all parties that have a legitimate interest.
MLRS TGW	HIGH	Establishing access to US information was challenging for MLRS. Secure communications links were established by providing encryption and communications equipment to partner nations. The flow of information between national program offices was difficult and required special accommodation.

released and then the release policy is further restricted. The lesson: Make sure release policies are well established before providing data to international partners. International incidents may occur if release policy is made more restrictive as a program progresses. People get upset. Countries feel insulted. Issues of this nature may rise to the highest levels of Government.

Special arrangements should be made for transmittal of technical information between countries. U.S. Policies for technology transfer do not seem to be consistent with international agreements for cooperative development. There are advocates and detractors for more openness. In a fully cooperative development, one would think that all national parties would bring all of their technical knowledge to the program. However, the U.S. has not yet made that level of commitment to international programs. Concern for security of information and a fear that vulnerabilities of other systems may be revealed, lead the U.S. to carefully scrutinize all requests for information.

h. User Participation

(1) Framework Element Analysis. This TMO Framework Element has mixed value for describing international programs. The value is related to the degree of coupling between partner-nation management processes. Table 26 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

(2) TMO Lessons Learned. User participation is important for any major development effort, particularly for establishing overall requirements, human system interface requirements and other user related requirements such as training and maintenance. In international programs, means for coordinating clarifications and updates of requirements is critical. Program management understanding of how the various Users plan to fight the system is critical. Understanding of how training for the system will be done is critical. Establishing an understanding of how the system will be tested in a user environment, usually called Initial Operational Test and Evaluation (IOT&E) in the U.S. is critical.

Table 26: User Participation

TMO Framework Element: User Participation		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	There was no international User consideration for HAWK development.
ROLAND	LOW	There was no international User consideration for Roland development, however, the US user was vitally concerned with ensuring that ROLAND met its advertised performance.
LANCE	LOW	There was no international User consideration for LANCE development.
MEADS	HIGH	User participation is typically less for European system development than for US development. Understanding this is important to participants in international programs. In the case of MEADS US participants, there is an expectation of early and continuous User involvement. However, the same is not true for other participants. The balance achieved for MEADS will be instructive and may be of use to other programs.
Inter-national Space Station	Low	This framework element may not apply to NASA because of the way NASA is organized. NASA both writes the requirements for its systems and then develops the systems. Astronauts can be looked at as users of the ISS, however, they did not get involved in writing a requirements document for the ISS. Astronauts do get involved in developing some of the requirements related to Human System Integration.
MLRS TGW	HIGH	International User participation was critical for establishing the basic requirements of TGW. This was recognized by including on the TGW Management Executive Committee both the national PM for MLRS and the national User representative.

i. Cost Share and Work Share

(1) Framework Element Analysis. This TMO Framework Element has mixed value for describing international programs. Its value relates to the international coupling. Table 27 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

Table 27: Cost Share and Work Share

TMO Framework Element: Cost Share and Work Share		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	There was no international Cost Share and Work Share consideration for HAWK development, although arrangements were made for co-production of HAWK in Europe and Japan.
ROLAND	LOW	There was no international Cost Share and Work Share consideration for Roland development, however, the US bought and produced ROLAND partially to offset European purchases of US systems such as HAWK
LANCE	LOW	There was no international User consideration for LANCE development.
MEADS	HIGH	Cost share and work share arrangements for MEADS are critical to continued participation by all parties. Establishing a method for managing overall work share to allow participation of national laboratories such as RDEC will be important if significant program involvement of these institutions is to occur.
Inter-national Space Station	Low	There was and is no consideration for cost share or work share related to the ISS. Participants pay for whatever hardware they contribute and they gain prestige from their participation.
MLRS TGW	HIGH	Cost share and work share were carefully managed for MLRS TGW. The program manager, who was a US Army Colonel, was responsible for balancing the overall work share. Unique arrangements were made to minimize foreign currency conversions.

(2) TMO Lessons Learned. Cost share and work share are not applicable to all international development efforts. If Cost share and work share are required in an international effort, then they must be balanced according to international agreement. The percentages are very important to the personnel from participating nations. Their authority to participate in the program is tied not only to overall cost, but also to cost share and work share.

It is important to establish mechanisms for managing cost share and work share early in the program. Having a process

managed directly by the International Program Office will enable access to national laboratories as well as to support contractors.

Ideally, an understanding should be reached that work share can be balanced over several program phases. For instance, if work share gets out of balance during development, then the possibility should exist to bring work share into balance during production. One way of doing this is to allocate proceeds from external sales to make up for shortfalls in work share. Countries are loath to pay other countries from their treasuries to make up for differences in work share.

j. Preparation of Contract Statements of Work (SOW)

(1) Framework Element Analysis. This TMO Framework Element has value for the review of tightly coupled international programs. Table 28 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

(2) TMO Lessons Learned. The primary lesson learned about preparation of contract SOWs for international development programs is that considerable time is required to obtain agreement of content by the participating nations. Each nation must go through an independent staffing process. This is time consuming. TMO is involved with development of the SOWs because SOWs for a major system development primarily address technical work to be performed.

The development of a SOW will typically be led by a senior technical person or persons. Having people in the process that are personable and able to make useful compromises with their international counterparts is extremely important. Also, the earlier issues are addressed, the better. A bad SOW is not more likely to gain approval as it gets older.

Table 28: Preparation of Contract SOWs

TMO Framework Element: Preparation of Contract Statements of Work (SOWs)		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	ZERO	There was no international coordination for preparation of SOWs
ROLAND	ZERO	There was no international coordination for preparation of SOWs
LANCE	ZERO	There was no international coordination for preparation of SOWs
MEADS	HIGH	National participant in MEADS, represented by its National Product Office has been keen to ensure its interests are represented in the MEADS contract SOWs.
Inter-national Space Station	ZERO	There was no international coordination for preparation of SOWs
MLRS TGW	HIGH	The SOW requirements had to go through each nation's decision processes and obtaining agreement was time consuming and laborious.

2. Program Feedback And Inputs Affecting TMO

a. International Executive Control

(1) Framework Element Analysis. This element adds little value to the International TMO Framework because the information that might be collected under this element has already been collected under the element "TMO Organizational Aspects."

(2) TMO Lessons Learned. No additional lessons learned from those captured by the International Organizational Aspects Framework Element.

b. TMO Funding

(1) Framework Element Analysis. This element adds little value to the International TMO Framework because the information that might be collected under this element has already been collected under the element “Cost Share and Work Share.”

(2) TMO Lessons Learned. No additional lessons learned from those captured by the Cost Share, Work Share TMO Framework Element.

c. National Interaction

(1) Framework Element Analysis. This TMO Framework Element has limited value for the review of loosely coupled and high value for tightly coupled international programs. **Error! Reference source not found.** summarizes the value of this element for an International TMO Framework for the six programs reviewed.

(2) TMO Lessons Learned. Regarding national interaction, not all international programs with international aspects have a combined international program office per se, however, by definition there is some national interaction in all international programs. Patience and diplomacy are important. European nations participate in more cooperative development efforts than does the U.S., and are more accustomed to the international environment. The U.S. acquisition personnel are learning, but are inexperienced with international programs. Technology transfer issues slow communication between the U.S. community and international programs, and a priority is placed on protecting information over making it available to the

Table 29: National Interaction

TMO Framework Element: National Interaction		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	MEDIUM	National Interaction limited mostly to coordination for purchase of complete HAWK missile systems, the Tech Data Package or individual system upgrades. However, US consultants reviewed European Operations because of missile failures blamed on U.S. Technical data package.
ROLAND	LOW	The burden of international coordination fell on the US contractor. There was a US/European Roland Liaison office, however this did not affect TMO.
LANCE	ZERO	There was no unique national interaction.
MEADS	HIGH	Formal national interaction is guided by the MEADS MOU, and this interaction between national participants and the MEADS program is through the Steering Committee. US personnel in the IPO are sometimes considered foreign nationals and sometimes US Government employees.
Inter-national Space Station	LOW	There was little national interaction for the related to TMO. As described in other framework elements, Boeing maintains the critical interfaces and does the system engineering work.
MLRS TGW	HIGH	Valuable information was obtained relating to the knowledge of personnel in the US acquisition process to accommodate international programs. The US acquisition structure was not prepared to address international programs, and a lot of energy was required to educate participants in the US acquisition process about international programs

international program. The international program office may be considered a foreign entity, and all of its personnel, including U.S. citizens, may be considered foreign agents.

d. U.S. Acquisition Review Prior to the Next Program Phase

(1) Framework Element Analysis. This TMO Framework Element has limited value for the review of loosely coupled and medium to high value for tightly coupled international programs. Table 30 summarizes the value of this element for an International TMO Framework for the six programs reviewed.

Table 30: U.S. Acquisition Review

TMO Framework Element: U.S. Acquisition Review Prior to Next Program Phase		
<u>PROGRAM</u>	<u>VALUE</u>	<u>INTERNATIONAL PROGRAM APPLICATION</u>
HAWK	LOW	HAWK considered international aspects of the program for its acquisition strategy. International sales reduced costs because missile quantities were increased. However, the process itself was unaffected by international aspects.
ROLAND	LOW	ROLAND was purchase from the European developers as a technical data package, and this influenced the acquisition process.
LANCE	ZERO	No International Influence on Acquisition Process
MEADS	HIGH	The US acquisition process is separate from the German and Italian acquisition processes and the processes are not synchronized. The US NPO is controlled by the International Program Office, but provides an interface to the US acquisition process. US acquisition regulations do not necessarily apply to the MEADS acquisition. This can lead to frustration among US employees assigned to the international program office.
Inter-national Space Station	ZERO	The ISS does not have acquisition phases that correspond to the US Defense acquisition phases.
MLRS TGW	MEDIUM	The US acquisition process was similar to that for other U.S. systems. One exception was that an effort was made to harmonize documentation so that a document developed to satisfy the US acquisition review process would also satisfy the European processes. Sometimes non-standard formats were used for documents to satisfy U.S. acquisition review. Requirements.

(2) TMO Lessons Learned. U.S. policy for conduct of international programs is confused, and this affects the acquisition review process. U.S. acquisition review prior to going into succeeding program phases is flexible and tailored to meet the needs of U.S. programs via DOD 5000 series documents. These documents acknowledge international programs, but need to be matured in this area. DOD 5000.2r, Mandatory Defense Acquisition Procedures requires the developing agency (such as the Army) to create standard acquisition documentation. This is in conflict with the need to generate one set of acquisition documents to satisfy all nations that participate. Continued debate is needed about the degree of U.S. commitment for international programs. Debate is needed about whether security concerns should dominate policy or whether effective partnership should dominate policy. Relaxing security restrictions would allow direct interaction between international program offices and the U.S. acquisition process, and would improve efficiency, however the negative side of this is added risk for the vulnerability of other U.S. systems.

APPENDIX: ACRONYMS

ACAT	Acquisition Category
AMCOM	Aviation and Missile Command
AMD	Air and Missile Defense
APB	Acquisition Program Baseline
C4ISP	Command, Control, Communications, Computers and Intelligence Support Plan
CM	Configuration Management
CPI	Critical Program Information
DOD	Department of Defense
DODD	DOD Directive
DODI	DOD Instruction
DT	Developmental Testing
DSMC	Defense Systems Management College
FOC	Full Operational Capability
FRP	Full Rate Production
HIS	Human System Integration
HWIL	HardWare In the Loop
IOC	Initial Operational Capability
IPO	International Product Office
ITRD	International Technical Requirements Document
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MEADS	Medium Extended Air Defense System
MICOM	Missile Command
MLRS	Multiple Launch Rocket System
MNS	Mission Need Statement
MOU	Memorandum of Understanding
MTBF	Mean Time Between Failures

NAMEADSMA	NATO MEADS Management Agency
NATO	North Atlantic Treaty Organization
NPO	National Product Office
NATO	North Atlantic Treaty Organization
NEPA	National Environmental Policy Act (NEPA)
ORD	Operational Requirements Document
OT	Operational Testing
PM	Program Manager
PMO	Program Management Office
RDEC	Research, Development and Engineering Center
SD&D	System Development and Demonstration
SEMP	System Engineering Management Plan
SOW	Statement Of Work
TEMP	Test and Evaluation Master Plan
TGW	Tactical Guided Warhead
TMO	Technical Management Oversight
TPM	Technical Performance Measure

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